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NASTRAN Supplemental Documentation for Modal Forced Vibration Analysis of Aerodynamically Excited Turbosystems

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FINAL REPORT

CONTRACT NAS3-24387

NATIONAL AERONAUTICS and SPACE ADMINISTRATION
Lewis Research Center
Cleveland, OH 44135

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SUMMARY

This report is a supplemental NASTRAN document for a new capability to determine the vibratory response of turbosystems subjected to aerodynamic excitation. Supplements to NASTRAN Theoretical, User's, Programmer's, and Demonstration Manuals are included.

Turbosystems such as advanced turbopropellers with highly swept blades, and axial-flow compressors and turbines can be analyzed using this capability. which has been developed and implemented in the April 1984 release of the general purpose finite element program NASTRAN.

The dynamic response problem is addressed in terms of the normal modal coordinates of these tuned rotating cyclic structures. Both rigid and flexible hubs/disks are considered. Coriolis and centripetal accelerations, as well as differential stiffness effects are included.

Generally non-uniform steady inflow fields and uniform flow fields arbitrarily inclined at small angles with respect to the axis of rotation of the turbosystem are considered as the sources of aerodynamic excitation. The spatial non-uniformities are considered to be small deviations from a principally uniform inflow. Subsonic and supersonic relative inflows are addressed, with provision for linearly interpolating transonic airloads.

A stand-alone program, AIRLOADS, has been additionally

developed to generate the vibratory airloads on the blades of the turbosystems. This program can be used as a pre-processor to NASTRAN.

Both NASTRAN and pre-processor capabilities are operational on the CRAY 1-S computer system at NASA's Lewis Research Center.

The work was conducted under Contract NAS3-24387 from NASA LeRC, Cleveland, Ohio, with Mrs. Marsha Nall as the Program Monitor.

ACKNOWLEDGEMENT

The authors avail themselves of this opportunity to express their sincere appreciation of the technical and administrative cooperation extended by Mrs. Marsha Nall, and Drs. Bob Kielb and Kris Kaza of NASA Lewis Research Center.

Secretarial assistance provided by Mrs. Nancy Smith in the compilation of this report is admirably acknowledged.

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NASTRAN THEORETICAL MANUAL

MODAL FORCED VIBRATION ANALYSIS OF AERODYNAMICALLY EXCITED TURBOSYSTEMS

1.1 INTRODUCTION

A new capability has been developed and implemented in NASTRAN to perform modal forced vibration analysis of turbosystems subjected to aerodynamic excitation.

Single- and counter-rotating advanced turboprops with significantly swept blades, and axial-flow compressors and turbines are examples of turbosystems that can be analyzed using this capability.

Generally non-uniform steady inflow fields and uniform flow fields arbitrarily inclined at small angles with respect to the axis of rotation of the turbosystem are considered as the aerodynamic sources of excitation. Subsonic and supersonic relative inflows are recognized, with a provision for linearly interpolating transonic aerodynamic loads.

The capability has been implemented in the April 1984 release of NASTRAN on the CRAY 1-S computer system at NASA's Lewis Research Center.

Highlights of the theoretical basis of the new capability (Ref. 1) are presented in this section. Details of the User's, Programmer's, and Demonstration Manuals are contained in Sections 2, 3, and 4, respectively.

1.2 PROBLEM DESCRIPTION

Figure 1.1 shows a single-rotation advanced turboprop, as an example of turbosystems, operating in a generally non-uniform steady inflow field.

Although the absolute inflow field does not change with time, the rotation of the turboprop results in velocities with oscillatory components relative to the blades. Relative velocities with harmonic components at the rotational frequency also exist in uniform flow fields when the turboprop axis of rotation is misaligned with the absolute flow direction.

Given such operating conditions, it is desired to,

1. determine the oscillatory loading distributions over the blades of the turboprop at various excitation frequencies, and

2. determine the resulting vibratory response (displacements, stresses, etc.) of the turboprop.

As per NASA's needs, the problem of determining the applied oscillatory airloads on the turbosystem blades has been addressed in a stand-alone development outside, and independent of, NASTRAN (Ref. 2). The stand-alone program, AIRLOADS, however, can also function as a pre-processor to NASTRAN analyses.

Determination of the modal vibratory response is discussed further in the following subsections.

1.3 THEORY

1.3.1 Structural Aspects

1. Structures of turbosystems are treated as tuned cyclic structures with identical mass, stiffness, damping, and constraint properties for all cyclic sectors. The structural modelling capabilities of NASTRAN for rotationally cyclic structures are fully admitted.

2. Turbosystems with both rigid and flexible hubs/disks are considered.

3. Differential stiffness effects due to centrifugal loads and any (externally specified) steady state airloads are included.

4. Coriolis and centripetal acceleration (stiffness softening) effects are taken into account.

5. Circumferential harmonic-dependent normal modes of tuned cyclic structures are used in formulating and solving the dynamic response problem in the frequency domain.

1.3.2 Aerodynamic Aspects

1. Aerodynamic modelling is essentially dictated by the unsteady aerodynamic theories used to determine the

unsteady blade loading distribution. Due to the use of two-dimensional cascade aerodynamic theories, the blade aerodynamic model comprises a series of chordwise strips stacked spanwise to cover the entire blade surface as shown in Figure 1.2.

2. Two-dimensional subsonic and supersonic cascade aerodynamic routines are utilized for generating the reactionary airloads on turbosystem blades due to oscillatory blade motions. Blade sweep effects are included in both routines. Transonic airloads are linearly interpolated.

3. Externally specified aerodynamic loads can be applied to any degree of freedom of the structural model. These degrees of freedom are not restricted to those used in generating reactionary airloads mentioned in point (2) above.

1.3.3 Equations of Motion and their Solution

The total translational and rotational displacements at any fixed point of the rotating and vibrating turbosystem, expressed in body-fixed coordinate systems, consist of

- steady state components due to the steady airloads and centrifugal loads, and

- vibratory components due to the vibratory excitation, superposed on the steady displacements.

The aerodynamic vibratory response problem of the turbosystem is treated herein in terms of the vibratory components of total displacements.

For an N-bladed tuned turbosystem, with structural coupling between blades via a relatively flexible hub, the equations of forced motion can be written as (Ref. 1)

$$
\begin{aligned}
[M^n]\{\ddot{u}^n\} &+ \Big[[B^n]^{visc.} + 2\Omega\,[B_1^n]\Big]\{\dot{u}^n\} \\
&+ \Big[[K^n]^{elas.} + [K^n]^{diff.} - \Omega^2\,[M_1^n]\Big]\{u^n\} \\
&- [Q^n]\{u^n\} = \{P^n\}^{aero.} ,
\end{aligned}
\qquad (1)
$$

and

$$
\{u^n\}_{side\ 2} = \{u^{n+1}\}_{side\ 1} , \quad n = 1, 2, \ldots, N . \qquad (2)
$$

The forcing term on the right hand side of equation (1) is entirely due to aerodynamic excitation. Cyclic sector numbers and their sides referred to in equation (2) are illustrated in Figure 1.3 .

In seeking solutions for the vibratory displacements u^n , for all n , based on the qualitative and quantitative nature of

the right hand side forcing functions, the following steps, applicable to tuned cyclic structures with rotational cyclic symmetry, are considered.

1. The displacements u^n (and the loads P^n) can be written as (Ref. 1)

$$\{u^n\} = \{\bar{u}^o\} + \sum_{k=1}^{k_L} \left[\{\bar{u}^{kc}\} \cos(\overline{n-1}\, ka) + \{\bar{u}^{ks}\} \sin(\overline{n-1}\, ka) \right] + (-1)^{n-1} \{\bar{u}^{N/2}\} . \tag{3}$$

This is a standing wave representation wherein the coefficients $\bar{u}^o$, $\bar{u}^{kc}$, $\bar{u}^{ks}$ and $\bar{u}^{N/2}$ are, in general, functions of time or frequency. For a given circumferential harmonic index k, by defining appropriate relations between $\bar{u}^{kc}$ and $\bar{u}^{ks}$ the above equation can be transformed to a travelling wave form (Ref. 1). The constants k_L and a are given by,

$$\left.\begin{aligned} k_L &= (N-1)/2 , \quad N \text{ odd} , \\ &= (N-2)/2 , \quad N \text{ even} , \\ \text{and} \quad a &= 2\pi / N . \end{aligned}\right\} \tag{4}$$

2. For a given circumferential harmonic index ,

$$\{u^{n,k}\} = \{\bar{u}^{kc}\} \cos(\overline{n-1}\, ka) + \{\bar{u}^{ks}\} \sin(\overline{n-1}\, ka) . \tag{5}$$

3. With the use of inter-segment compatibility constraint conditions (equation 2)

$$\{\bar{u}^{kc}\} = [G_{ck}(k)]\{\bar{u}^{K}\}, \text{ and} \tag{6}$$

$$\{\bar{u}^{ks}\} = [G_{sk}(k)]\{\bar{u}^{K}\}, \tag{7}$$

where $\bar{u}^K$ is an independent displacement vector consisting of $\bar{u}^{kc}$ and $\bar{u}^{ks}$ degrees of freedom from the interior and side 1 of a cyclic sector. The transformations G_{ck} and G_{sk} are functions of the circumferential harmonic k, and express the side 2 degrees of freedom in terms of those on side 1.

4. Equation (5) can then be written as

$$\{u^{n,k}\} = \left[\cos(\overline{n-1}\,ka)\,[G_{ck}] + \sin(\overline{n-1}\,ka)\,[G_{sk}]\right]\{\bar{u}^{K}\}. \tag{8}$$

5. The real eigenvalue problem, for a given k, can then be stated from equation (1) as

$$\left[-\omega^2[\bar{M}^K] + [\bar{K}^K]\right]\{\bar{\bar{u}}^K\} = 0, \tag{9}$$

where

$$\{\bar{u}^K\} = \{\bar{\bar{u}}^K\}\,e^{i\omega t}, \tag{10}$$ contd.

$$\left.\begin{aligned}[\bar{M}^K] &= [G_{ck}]^T[M^n][G_{ck}] + [G_{sk}]^T[M^n][G_{sk}], \text{ and} \\ [\bar{K}^K] &= [G_{ck}]^T[K^n][G_{ck}] + [G_{sk}]^T[K^n][G_{sk}].\end{aligned}\right\} \quad (10)$$

6. The eigenvectors $[\bar{\phi}^K]$ obtained from the solution of equation (9), can be used to introduce the modal coordinates $\bar{\xi}^K$ as

$$\{\bar{u}^K\} = [\bar{\phi}^K]\{\bar{\xi}^K\}. \quad (11)$$

7. The modal equations of forced motion of the turbosystem, for a given circumferential harmonic index k, can then be written from equation (1)

$$[\bar{\bar{M}}^K]\{\ddot{\bar{\xi}}^K\} + [\bar{\bar{B}}^K]\{\dot{\bar{\xi}}^K\} + [\bar{\bar{K}}^K]\{\bar{\xi}^K\} - [\bar{\bar{Q}}^K]\{\bar{\xi}^K\} = [\bar{\phi}^K]^T\{\bar{P}^K\}, \quad (12)$$

where

$$[\bar{\bar{M}}^K] = [\bar{\phi}^K]^T[\bar{M}^K][\bar{\phi}^K], \quad (13) \text{ contd.}$$

$$
\left.
\begin{aligned}
[\bar{\bar{B}}^K] &= [\bar{\phi}^K]^T[\bar{B}^K][\bar{\phi}^K] \;, \\
[\bar{\bar{K}}^K] &= [\bar{\phi}^K]^T[\bar{K}^K][\bar{\phi}^K] \;, \\
[\bar{\bar{Q}}^K] &= [\bar{\phi}^K]^T[\bar{Q}^K][\bar{\phi}^K] \;, \\
[\bar{Q}^K] &= [G_{ck}]^T[Q^n][G_{ck}] + [G_{sk}]^T[Q^n][G_{sk}] \;, \\
\text{and} & \\
\{\bar{P}^K\} &= [G_{ck}]^T\{\bar{P}^{kc}\} + [G_{sk}]^T\{\bar{P}^{ks}\} \;.
\end{aligned}
\right\} \quad (13)
$$

8. For a given circumferential harmonic index k, $\bar{P}^{kc}$ and $\bar{P}^{ks}$ are the circumferential harmonic components of the total external excitation. Such excitation due to aerodynamic sources is discussed in Refs. 1 and 2.

9. The generalized oscillatory aerodynamic reaction matrix $\bar{\bar{Q}}^K$ can be written as

$$
[\bar{\bar{Q}}^K] = [\bar{\phi}^{kc}]^T[Q^n][\bar{\phi}^{kc}] + [\bar{\phi}^{ks}]^T[Q^n][\bar{\phi}^{ks}] \;, \quad (14)
$$

where

$$
[\bar{\phi}^{kc}] = [G_{ck}][\bar{\phi}^K] \;, \quad (15) \text{ contd.}
$$

and

$$[\bar{\phi}^{ks}] = [G_{sk}][\bar{\phi}^{K}] \qquad (15)$$

are the 'cosine' and 'sine' component mode shapes of eigenvectors $\bar{\phi}^{K}$ Equation (14) is rewritten as

$$[\bar{\bar{Q}}^{K}] = [Q^{c}_{ii}] + [Q^{s}_{ii}] \qquad (16)$$

For turbosystem structures with flexible hub/disk,

a) Q^{c}_{ii} and Q^{s}_{ii} exist when the circumferential harmonic index $k \neq 0$ and $\neq N/2$ when N, the total number of cyclic segments in the structure, is even, and

b) only Q^{c}_{ii} exists when $k = 0$ or $N/2$, N even.

For turbosystem structures with rigid hub/disk, each cyclic segment of the structure behaves structurally independent of its adjacent segments. Degrees of freedom at segment boundaries are completely constrained to zero. The only possible structural modes are those akin to $k = 0$ modes with fixed inter-segment boundaries. Only Q^{c}_{ii} exists.

Derivation of Q_{ii} is discussed in detail in Ref. 1.

10 . Equation (12) can now be solved for $\bar{\xi}^K$. Substitution in equation (11), and equation (8) yields $u^{n,k}$.

11 . Repeating steps 2 through 10 for all applicable circumferential harmonic indices, and substitution in equation (3), result in u^n for all n .

12 . Other dynamic responses such as stresses, etc., can be obtained for all sectors of the turbosystem by current NASTRAN procedures.

The procedure described above for the solution of circumferential harmonic components of dynamic response, for a given circumferential harmonic index, has been implemented in the April 1984 release of NASTRAN on the CRAY 1-S computer system at NASA LeRC.

An overall flowchart of the solution procedure is shown in Figure 1.4 .

Supplements to the NASTRAN User's, Programmer's, and Demonstration manuals are presented in the following sections.

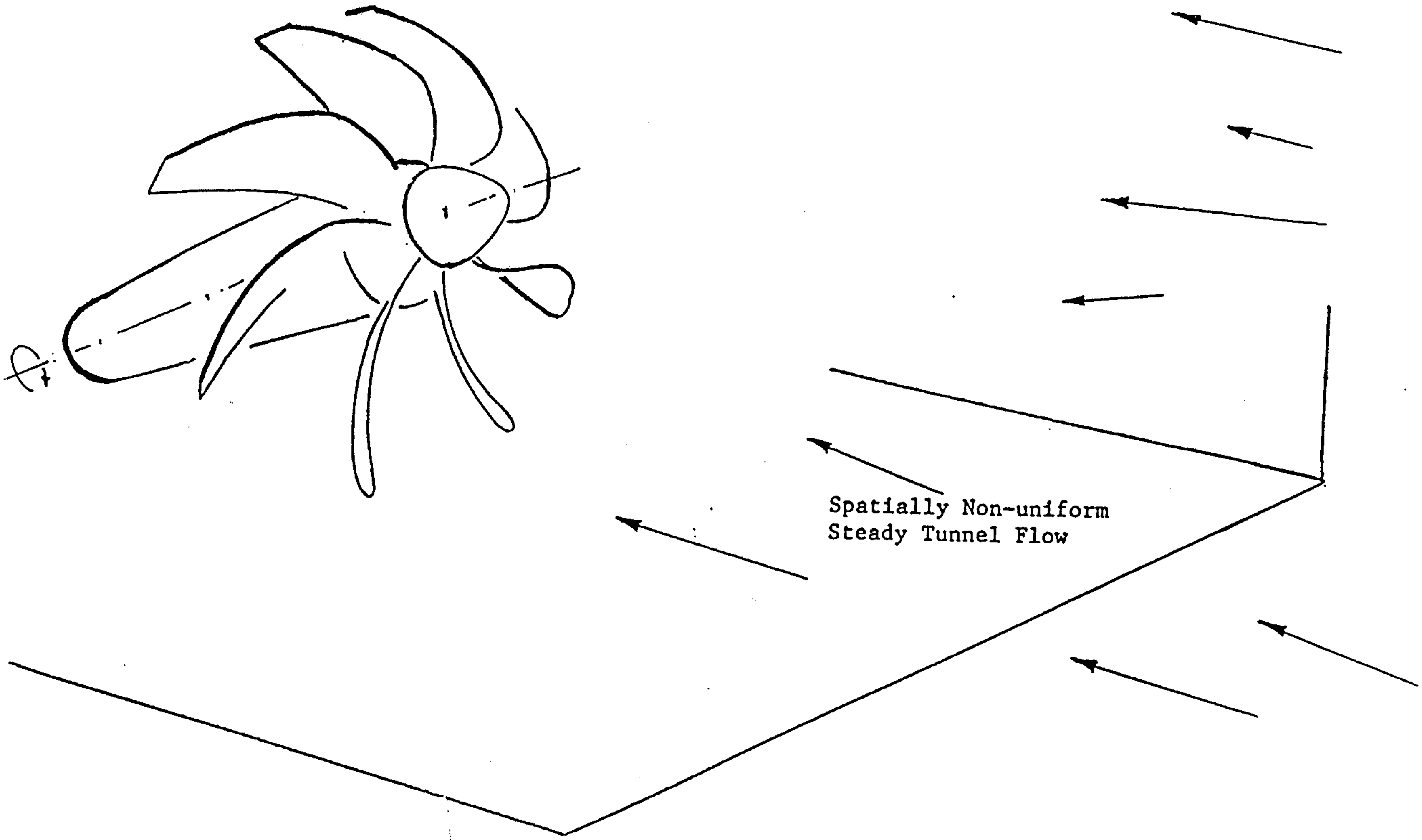


Figure 1.1 Advanced Turboprop in a Generally Non-Uniform Steady Inflow Field

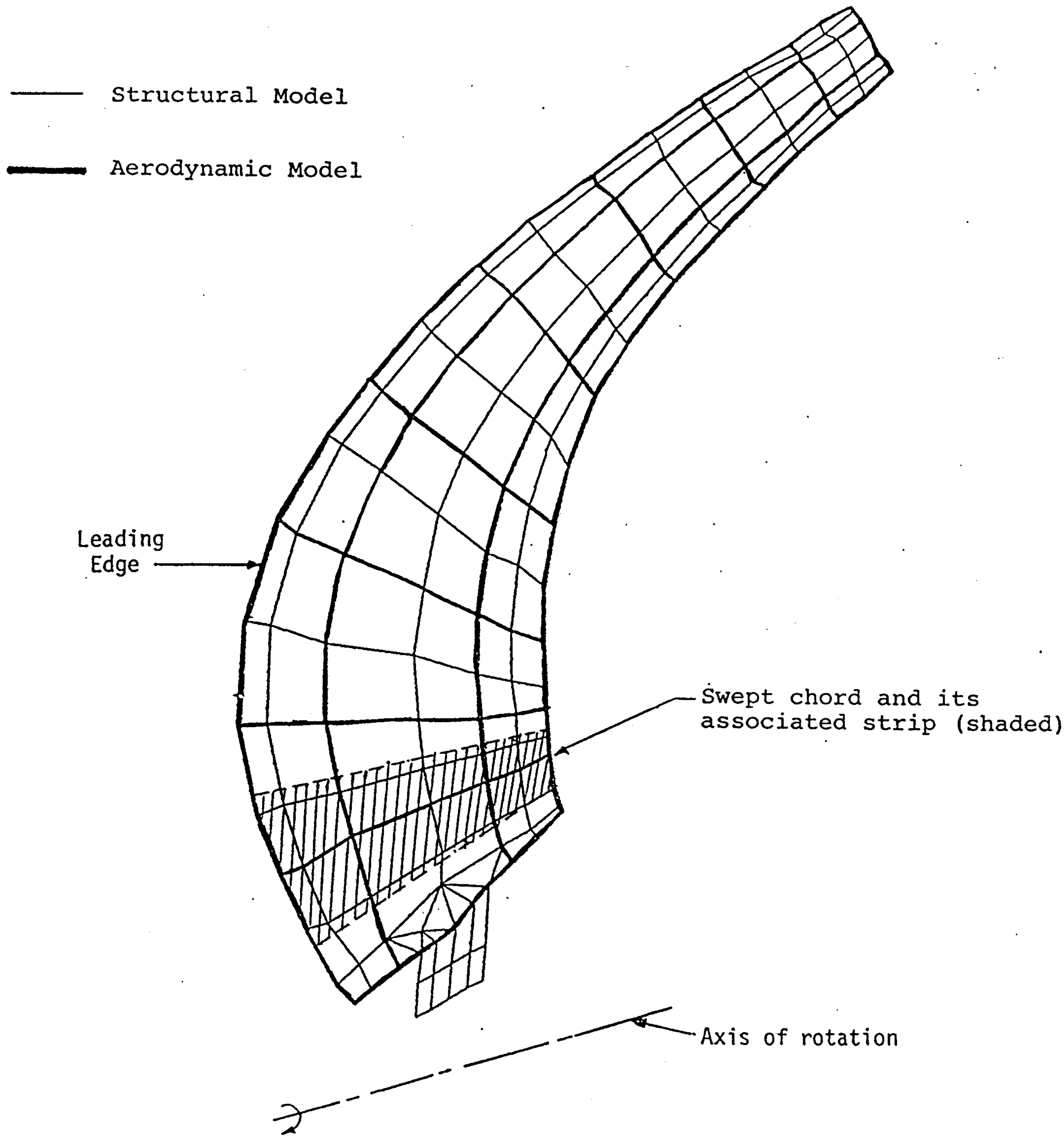
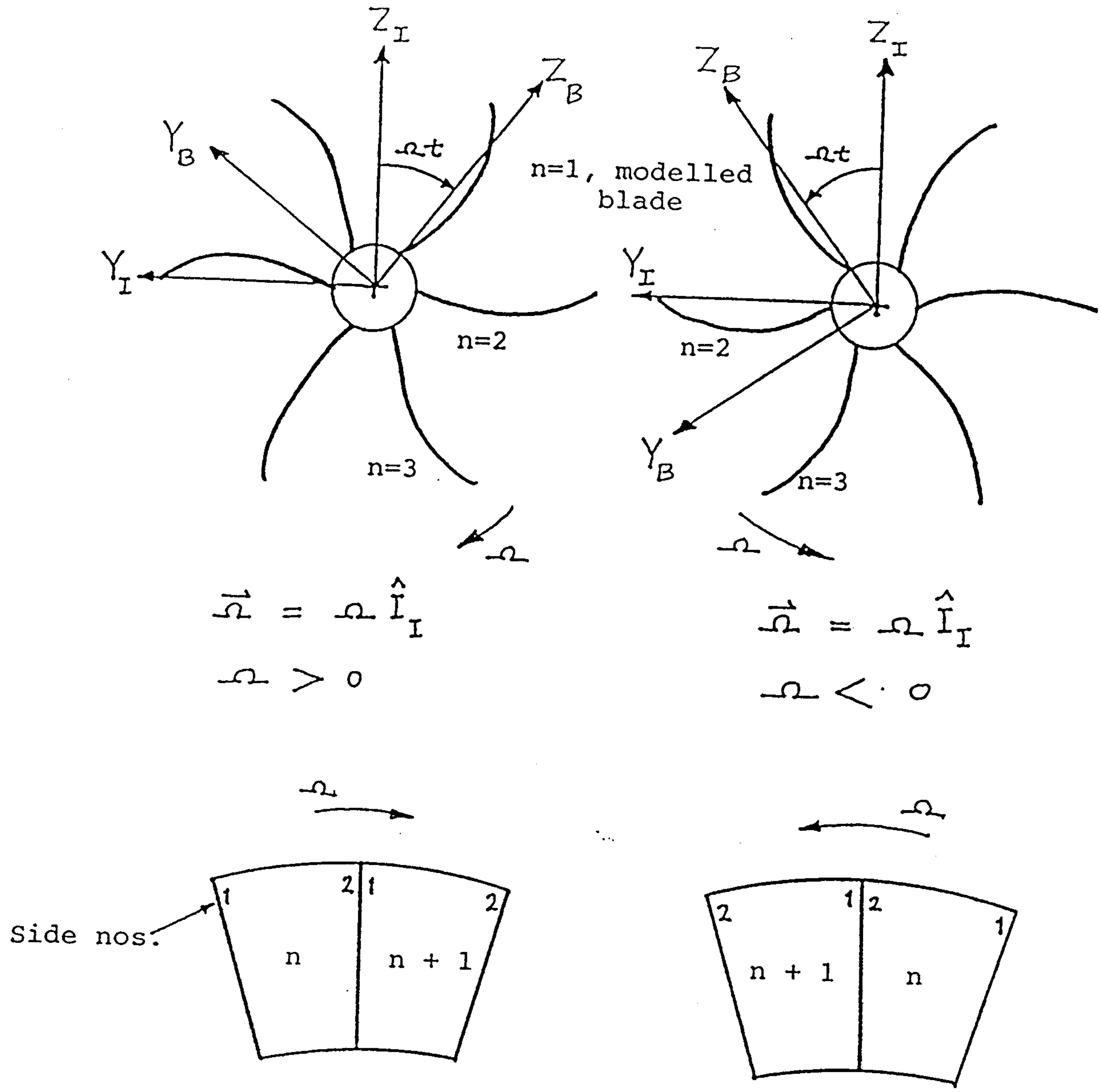


Figure 1.2 NASTRAN Aerodynamic Model of Turboprop Blade for 2-D Cascade Theories (Ref. 1)



NOTES

1. $\vec{\Omega}$ is the angular velocity of the $X_B Y_B Z_B$ (Basic) coordinate system w.r.t. the $X_I Y_I Z_I$ (Inertial) coord. system.
2. Modelled sector is always n=1 st. sector.
3. Sector, and side numbers within a sector, increase in the direction of $|\Omega t|$.

Figure 1.3 Cyclic Sector and Side Numbering Convention

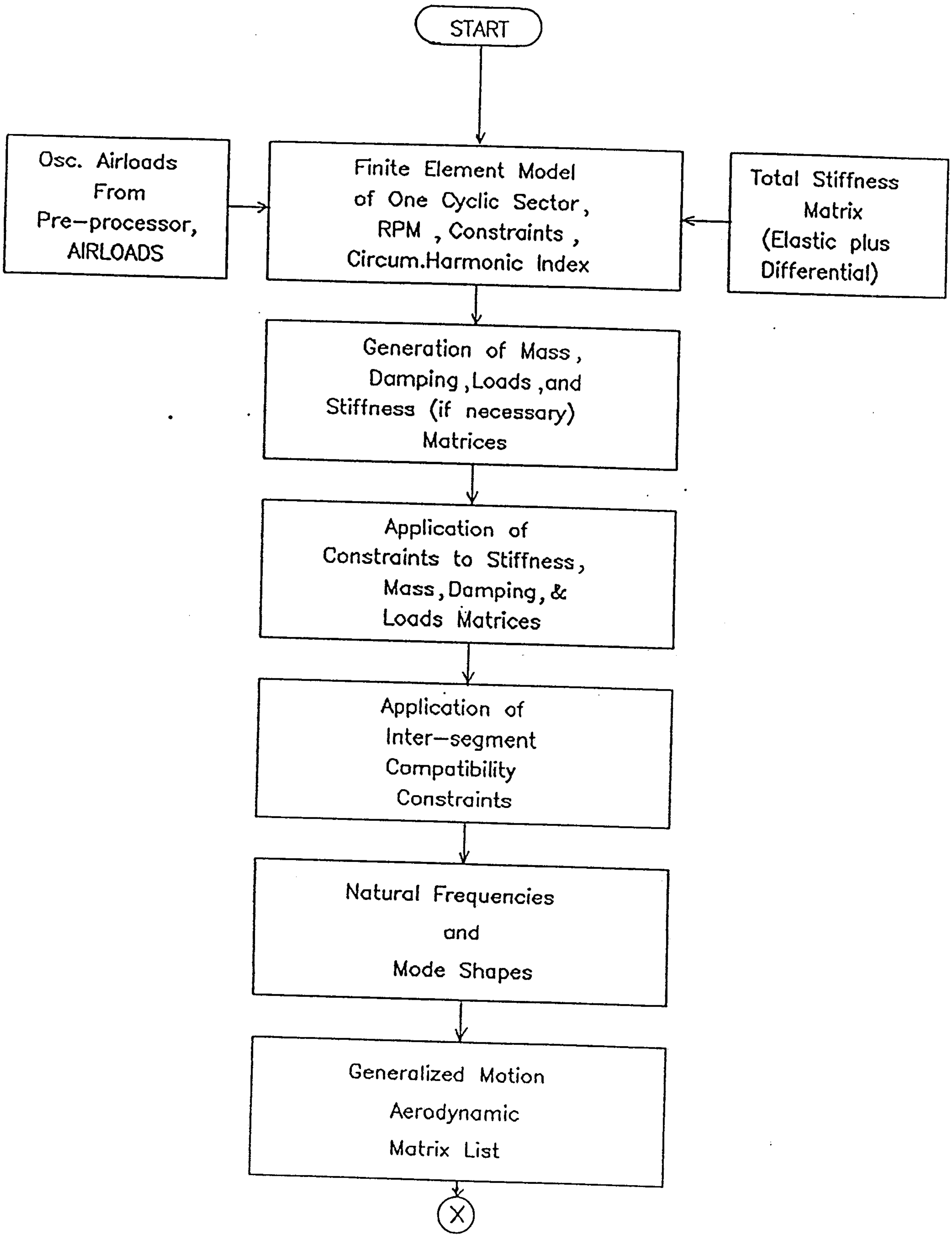


Figure 1.4 Overall Flowchart of Modal Forced Vibration Analysis Capability for Aerodynamically Excited Turbosystems

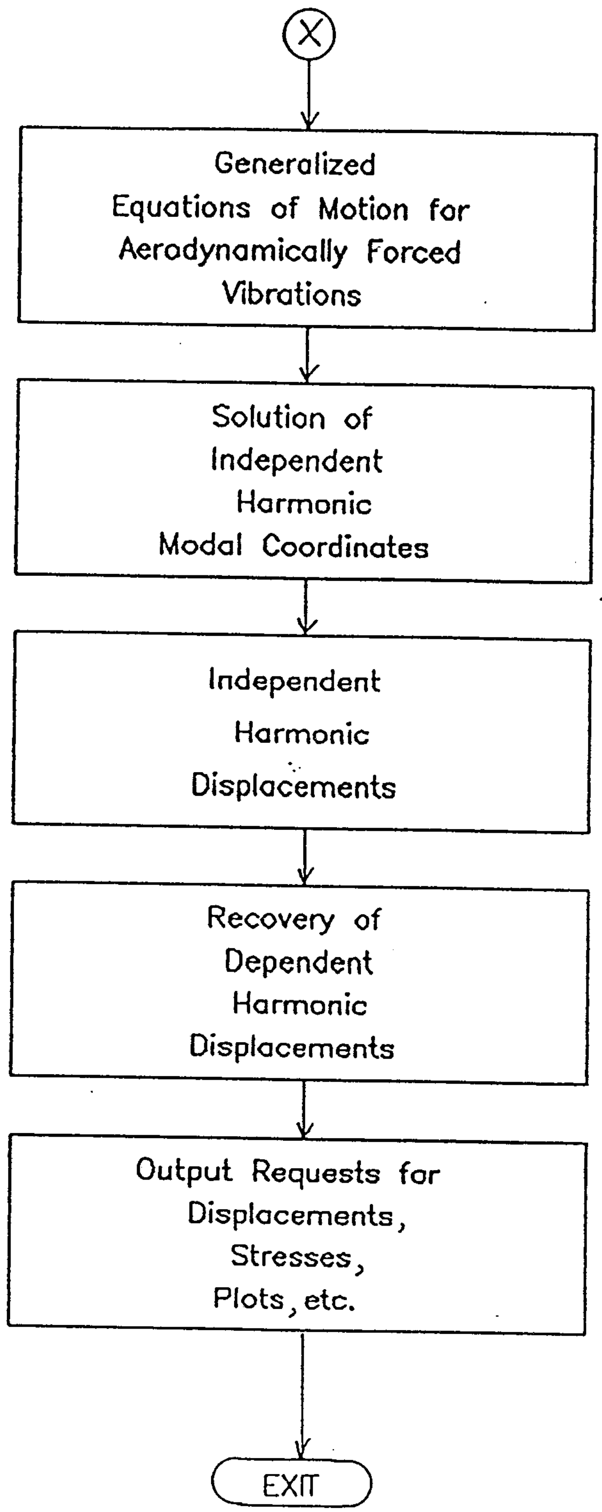


Figure 1.4 Concluded

SECTION 2

SUPPLEMENT TO
NASTRAN USER'S MANUAL

MODAL FORCED VIBRATION ANALYSIS OF AERODYNAMICALLY EXCITED TURBOSYSTEMS

2.1 INTRODUCTION

All aspects of conducting modal forced vibration analysis of aerodynamically excited turbosystems rotating about their axis of symmetry are presented from a NASTRAN user's viewpoint in this section.

Generally stated, the complete problem of modal forced vibration analysis of aerodynamically excited turbosystems can be considered in four distinct phases (Figure 2.1):

Phase 1 to conduct differential stiffness analysis,

Phase 2 to investigate aeroelastic stability at the operating point,

Phase 3 to generate the applied oscillatory airloads at the operating condition, and

Phase 4 to finally conduct the modal forced vibration analysis.

All of the four phases are illustrated by the example presented in the Demonstration manual supplement, Section 4.

Phase 1 uses DISP APP Rigid Format 4 with ALTERS to save the total stiffness matrix.

Phase 2 uses AERO APP Rigid Format 9 (Refs. 3 and 4).

Phase 3 uses the pre-processor program AIRLOADS (Ref. 2). This phase can be conducted using any alternative procedure for airloads generation.

Phase 4 uses DISP APP Rigid Format 8 with the MFVAAET Alter package. This phase is discussed in detail in the following subsections.

2.2 NASTRAN MODEL

The user models one rotationally cyclic sector (segment) of the entire structure as shown in Figure 2.2. This modelled sector is considered as the n = 1 st. sector. Each cyclic sector is defined with two sides which identify its boundaries with the two adjacent cyclic sectors (Figure 1.3).

The side 2 degrees of freedom are related to those on side 1 via the circumferential harmonic index. The modelling of rigid hub/disk conditions is accomplished by completely constraining all degrees of freedom on both sides of the cyclic sector to zero. Although the circumferential harmonic index is irrelevant in such situations, it should be selected as zero for computational efficiency.

The structural model is prepared using the general capabilities of NASTRAN for modelling rotationally cyclic structures.

The aerodynamic model for the generation of reactionary

airloads comprises a grid defined by the intersection of a series of chords and "computing stations" (Figure 1.2). The chords are selected normal to any spanwise reference curve such as the blade leading edge. The choice of the number and location of the chords and the computing stations is dictated by the expected variation of the relative flow properties across the blade span, and the complexity of the mode shapes exhibited by the propeller blade. Due to its resemblance to the structural model of the blade, and the adequacy of a relatively coarse grid to describe the spanwise flow variations, the aerodynamic model is chosen as a subset of the structural model as shown in Figure 1.2.

The aerodynamic grid is specified on STREAML1 bulk data cards.

2.2.1 Coordinate Systems

In order to conveniently pose and solve the aerodynamically forced vibration problem of turbosystems, a number of coordinate systems have been defined. Figure 2.2 illustrates these

coordinate systems for an advanced turbopropeller with its axis of rotation mounted at an angle with respect to the tunnel mean flow.

Each of these coordinate systems is described as follows:

- $X_T Y_T Z_T$ Tunnel coordinate system

  * This is defined to conveniently specify the velocity components of the spatially non-uniform tunnel free stream. It can be suitably oriented based on the available tunnel data. In the special case of aerodynamic excitation in uniform inflow, the tunnel coordinate system is oriented such that the $X_T Z_T$ plane is parallel to the $X_I Z_I$ plane of the inertial coordinate system as shown in Figure 2.3. The origin of the $X_T Y_T Z_T$ system is arbitrarily located. The inclination angle of the turbosystem axis of rotation with respect to the tunnel flow also lies in a plane parallel to $X_I Z_I$ plane. The uniform flow is directed along $+X_T$ axis.

- $X_I Y_I Z_I$ Inertial coordinate system

  * In the present problem, this coordinate system is used to relate the quantities in the tunnel and the basic coordinate systems. The orientation of this coordinate system is completely arbitrary except for the X_I axis to be parallel to, and in the direction of, X_B axis of the basic coordinate system described next. The zero

reference for time/phase measurements is defined when the inertial and the basic coordinate systems are parallel.

All of the following NASTRAN coordinate systems are fixed to the rotating turbosystem.

- $X_B Y_B Z_B$ Basic coordinate system

  * This coordinate system has its X_B axis coincident with the turbosystem axis of rotation, and directed aftward. Location of the origin is arbitrary. The $X_B Z_B$ plane contains (approximately) the maximum planform of the modelled blade. The definition of this coordinate system is consistent with the theoretical developments of the 2-d cascade unsteady aerodynamics presently incorporated in the Bladed Disks Computer Program (Ref. 1).

- $X_S Y_S Z_S$ (Blade) shank-fixed coordinate system

  * The principal advantage of this shank-fixed coordinate system is in modelling changes in the blade setting angles by a simple 3 x 3 transformation matrix relating to the basic coordinate system. Z_S coincides with the blade shank axis. The definition of the coordinate system otherwise is arbitrary.

- $X_G Y_G Z_G$ Grid point location and displacement coordinate systems

* Any number of such rectangular, cylindrical, or spherical coordinate systems can be completely arbitrarily defined to locate grid points of the NASTRAN model, as well as request output at these grid points. All of the $X_G Y_G Z_G$ coordinate systems used for output requests collectively form the NASTRAN global coordinates system.

- $\bar{x}_{\bar{s}} \bar{y}_{\bar{s}} \bar{z}_{\bar{s}}$ Internally generated coordinate system on swept chord $\bar{s}$

  * This coordinate system is generated within the present Bladed Disks Computer Program, and is used to define flow and motion properties for the unsteady aerodynamic theories on a given swept chord $\bar{s}$. It is located at the blade leading edge with the $\bar{x}_{\bar{s}}$ directed aftward along the chord $\bar{s}$. $\bar{y}_{\bar{s}}$ is defined normal to the blade local mean surface.

2.3 EXECUTIVE CONTROL DECK

The salient points are noted as follows:

1. The NASTRAN card is required immediately preceding the ID card in the Executive Control Deck, and must contain, at least, the following operational parameter:

   NASTRAN SYSTEM (93) = 1

   This invokes the sweep effects in subsonic and supersonic reactionary aerodynamic routines, and is suggested for use even when sweep effects are negligible. In all cases where STREAML2 bulk data cards are obtained from AIRLOADS program, this card is required.

2. SOL 8 and APP DISP must be selected.

3. The alter package, MFVAAET, (Modal Forced Vibration Analysis of Aerodynamically Excited Turbosystems) must be included. The READFILE capability of NASTRAN can be utilized as follows:

   READFILE MFVAAET

2.4 CASE CONTROL DECK

2.4.1 Subcase Definitions

The PARAMeter KMAX (≥ 0, $\leq$ NSEGS/2 for even NSEGS, $\leq$ (NSEGS-1)/2 for odd NSEGS) determines the number,

order and meaning of subcases as follows:

The number of subcases is equal to FKMAX, where

$$
\begin{aligned}
\text{FKMAX} &= 1, \text{ if KMAX } = 0, \\
&= 1 + 2*\text{KMAX}, \text{ if } 0 < \text{KMAX} \leqslant (\text{NSEGS}-1)/2, \text{ NSEGS odd}, \\
&= 1 + 2*\text{KMAX}, \text{ if } 0 < \text{KMAX} \leqslant (\text{NSEGS}-2)/2 \text{ NSEGS even}, \\
&\quad \text{and} \\
&= \text{NSEGS}, \text{ if KMAX} = \text{NSEGS}/2, \text{ NSEGS even}.
\end{aligned}
$$

SUBCASE 1 ('k' = 0)
SUBCASE 2 ('k' = 1c)
SUBCASE 3 ('k' = 1s)
SUBCASE 4 ('k' = 2c)
SUBCASE 5 ('k' = 2s)
.
.
.
SUBCASE FKMAX ('k' = KMAXs).

In the event that NSEGS is even and KMAX = NSEGS/2, Subcase FKMAX will represent 'k' = KMAXc as KMAXs does not exist.

Circumferential harmonic components of directly applied loads are specified under the appropriate subcases. With RLOADi bulk data cards, null loads need not be specified by the user.

2.4.2 Other Data Selection Items

1. The SPC and MPC request must appear above the subcase level and may not be changed.

2. METHOD must be used to select an EIGR bulk data card.

3. FREQUENCY must be selected and must be above the subcase level.

4. FREQUENCY must be used to select one and only one FREQ, FREQ1 or FREQ2 card from the Bulk Data deck.

5. Direct input matrices are not allowed.

6. OFREQ must not be used.

7. DLOAD must be used to define a frequency-dependent loading condition for each subcase. For frequency-dependent loads, subcases without loads need not refer to a DLOAD card.

The following printed output, sorted by frequency (SORT1) or by point number or element number (SORT2), is available, either as real and imaginary parts or magnitude and phase angle (0° - 360° lead), for the list of frequencies specified:

1. Displacements, velocities, and accelerations for a list of PHYSICAL points (grid points and extra scalar points introduced for dynamic analysis) or SOLUTION points (points used in formulation of the general K system).

2. Nonzero components of the applied load vector and single-point forces of constraint for a list of PHYSICAL points.

3. Stresses and forces in selected elements (ALL available only for SORT1).

The following plotter output is available for Frequency Response calculations:

1. Undeformed plot of the structural model.

2. X-Y plot of any component of displacement, velocity, or acceleration of a PHYSICAL point or SOLUTION point.

3. X-Y plot of any component of the applied load vector or single-point force of constraint.

4. X-Y plot of any stress or force component for an element.

The data used for preparing X-Y plots may be punched or printed in tabular form . Also, a printed summary is prepared for each X-Y plot which includes the maximum and minimum values of the plotted function.

The following items relate to Bulk Data restrictions:

1. SUPORT cards are not allowed.

2. EPOINT cards are not allowed.

3. SPOINT cards are not allowed.

4. CYJOIN cards are required.

The following parameters are used in Modal Forced Vibration Analysis of Aerodynamically Excited Turbosystems:

1. GRDPNT - optional - A positive integer value of this parameter will cause the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.

2. WTMASS - optional - The terms of the structural mass matrix

are multiplied by the real value of this parameter when they are generated in EMA. Not recommended for use in hydroelastic problems.

3. COUPMASS - fixed - Only lumped mass matrices must be used.

4. GKAD - optional - The BCD value of this parameter is used to tell the GKAD module the desired form of matrices KDD, BDD and MDD. The BCD value can be FREQRESP or TRANRESP. The default is TRANRESP.

   NOTE: Remember to define parameters G, W3 and W4. See Section 9.3.3 (DIRECT DYNAMIC MATRIX ASSEMBLY) Pages 9.3-7 and 9.3-8 of the NASTRAN Theoretical manual for further details.

5. LGKAD - optional - The integer value of this parameter is used in conjunction with parameter GKAD. If GKAD = FREQRESP then set LGKAD = 1, if GKAD = TRANRESP set LGKAD = -1. The default value is -1.

6. G - optional - The real value of this parameter is used as a uniform structural damping coefficient in the formulation of dynamics problems. Not recommended for use in hydroelastic problems (use GE on MAT1).

7. W3 - optional - The real value of this parameter is used as a pivotal frequency for uniform structural damping if parameter GKAD = TRANRESP. In this case W3 is required if uniform structural damping is desired. The default value is 0.0.

8. W4 - optional - The real value of this parameter is used as a

pivotal frequency for element structural damping if parameter GKAD = TRANRESP. In this case W3 is required if structural damping is desired for any of the structural elements. The default value is 0.0.

9. NSEGS - required - The integer value of this parameter is the number of identical segments in the structural model.

10. CYCIO - required - The integer value of this parameter specifies the form of the input and output data. A value of +1 is used to specify physical segment representation, and a value of -1 for cyclic transform representation. The value of CYCIO must be set to -1.

11. CYCSEQ - fixed - The integer value of this parameter specifies the procedure for sequencing the equations in the solution set. A value of +1 specifies that all cosine terms should be sequenced before all sine terms, and a value of -1 for alternating the cosine and sine terms. The value of CYCSEQ has been set to -1.

12. CTYPE - fixed - The BCD value of this parameter defines the type of cyclic symmetry as follows:

    (1) ROT - rotational symmetry

13. KMAX - required - The integer value of this parameter specifies the maximum value of the harmonic index, and is used in subcase definition. There is no default for this parameter. The maximum value that can be specified is NSEGS/2.

14. KMIN - optional - The integer value of this parameter specifies the minimum value of the harmonic index.

If KMIN ($\geqslant 0$, default = 0) equals KMAX, then Parameter KINDEX is internally defined equal to KMIN and KMAX. User supplied KINDEX is ignored.

If KMIN differs from KMAX, then KINDEX (KMIN $\leqslant$ KINDEX $\leqslant$ KMAX) must be specified.

15. KINDEX - optional, but see Parameter KMIN - Circumferential harmonic index. No default.

16. NLOAD - fixed - The integer value of this parameter is the number of static loading conditions. The value of NLOAD is internally computed.

17. NOKPRT - optional - An integer value of +1 for this parameter will cause the current harmonic index, KINDEX, to be printed at the top of the harmonic loop. The default is +1.

18. RPS - optional - The real value of this parameter defines the rotational speed of the structure in revolutions per unit time. The default is 0.0.

19. LFREQ and HFREQ - required unless LMODES is used - The real values of these parameters give the frequency range (LFREQ is lower limit, and HFREQ is upper limit) of the modes to be used in the modal formulation.

20. LMODES - used unless set to 0 - The integer value of this parameter is the number of lowest modes to be used in the modal formulation. The default is to use all modes.

21. MINMACH - optional - This is the minimum Mach number at and above which the supersonic unsteady cascade theory is valid. The default is 1.01.

22. MAXMACH - optional - This is the maximum Mach number at and below which the subsonic unsteady cascade theory is valid. The default is 0.80.

23. IREF - optional - This defines the reference streamline number. IREF must be equal to an SLN on a STREAML2 bulk data card. The default value, -1, represents the blade tip streamline. If IREF does not correspond to a valid SLN, the default is taken.

24. KGGIN - optional - A positive integer value of this parameter indicates that the user-supplied stiffness matrix is to be read from tape (GINO file INPT) via the INPUTT1 module in the rigid format. The default is -1.

25. Q - required - The real value of this parameter specifies the inflow dynamic pressure, based on the density and velocity on STREAML2 card for reference (PARAM IREF) streamline.

26. BOV - required - The real value of this parameter equals the ratio of the semichord to the velocity on STREAML2 card for

reference (PARAM IREF) streamline.

2.5 BULK DATA DECK

No new bulk data cards have been introduced to conduct modal aerodynamically forced vibration analysis of turbosystems.

Some remarks on the use of some of the bulk data cards are offered as follows:

CYJOIN. This card is used to list the corresponding GRID points on sides 1 and 2 of the modelled cyclic sector.

In case of rigid hub/disk conditions, the GRID points listed on this card must be totally fixed. The Parameters KMAX, KMIN, and KINDEX must be identically zero.

In case of flexible hub/disk, the data on this card must reflect such boundary connections. Parameters KMAX, KMIN, and KINDEX are truly active and meaningful. The displacement coordinate systems for any pair of corresponding GRID points must be axi-symmetrically compatible, i.e., the coordinate system for side 1 GRID point must completely coincide with that for the corresponding GRID point on side 2, when the side 1 coordinate system is rotated as a rigid body about the axis of rotation, and moved to side 2.

AERO. The variables on this card represent the conditions for the entire blade/turbosystem as a whole. The values of these

variables on the reference streamline are assigned to also represent those for the entire blade/turbosystem.

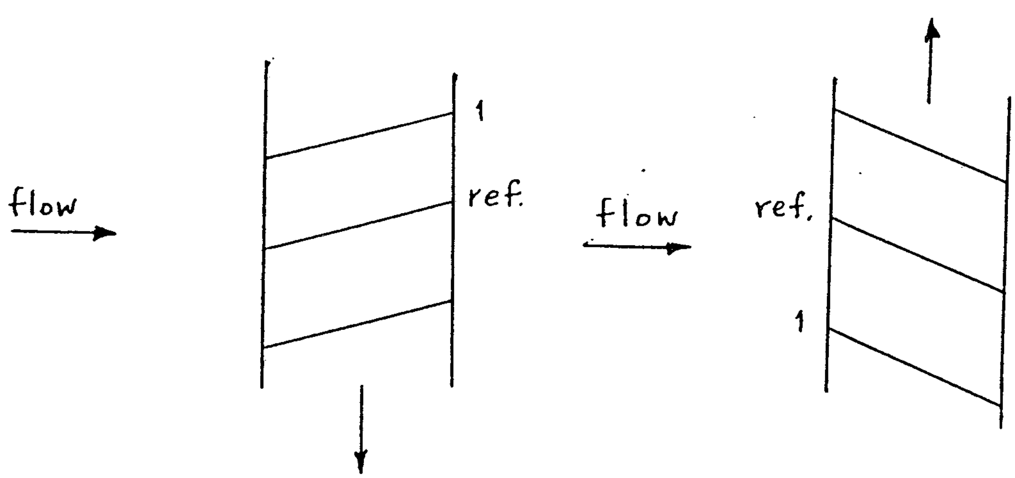
The reference streamline is picked by the user (PARAM IREF), and defaults to tip streamline otherwise.

STREAML2. This card defines the unsteady aerodynamic data for a given streamline.

Figure 2.4 illustrates some of the definitions pertinent to swept blade aerodynamics.

MKAERO*i*. The reduced frequency on these cards is based on the semichord and velocity on STREAML2 card for reference streamline.

Positive inter-blade phase angle is taken when, in the following sketch, blade 1 LEADS the reference blade.



Input Data Card CYJØIN

Description: Defines the boundary points of a segment for cyclic symmetry structural models

Format and Example:

1	2	3	4	5	6	7	8	9	10
CYJØIN	SIDE	C	G1	G2	G3	G4	G5	G6	abc
CYJØIN	1		7	9	16	25	33	64	ABC

+bc	G7	G8	G9	-etc.-					
+BC	72								

Alternate Form

CYJØIN	SIDE	C	GID1	"THRU"	GID2				
CYJØIN	2	S	6	THRU	32				

Field	Contents
SIDE	Side identification (Integer 1 or 2)
C	Coordinate System (BCD value R,C or S or blank)
Gi,GIDi	Grid or scalar point identification numbers (Integer > 0)

Remarks:

1. CYJØIN bulk data cards are only used for cyclic symmetry problems. A parameter (CTYPE) must specify rotational or dihedral symmetry.
2. For rotational symmetry problems there must be one logical card for side 1 and one for side 2. The two lists specify grid points to be connected, hence both lists must have the same length.
3. For dihedral symmetry problems, side 1 refers to the boundary between segments and side 2 refers to the middle of a segment. A coordinate system must be referenced in field 3, where R = rectangular C = cylindrical and S = spherical.
4. All components of displacement at boundary points are connected to adjacent segments, except those constrained by SPC, MPC or ØMIT.

Input Data Card AERØ Aerodynamic Physical Data

Description: Gives basic aerodynamic parameters.

Format and Examples

1	2	3	4	5	6	7	8	9	10
AERØ	ACSID	VELØCITY	REFC	RHØREF	SYMXZ	SYMXY			
AERØ	3	1.3+4	100.	1.-5		1			

Field	Contents
ACSID	Aerodynamic coordinate system identification (Integer $\geq$ 0). See Remark 2.
VELØCITY	Velocity (Real).
REFC	Reference length (for reduced frequency) (Real).
RHØREF	Reference density (Real).
SYMXZ	Symmetry key for aero coordinate x-z plane (Integer) (+1 for sym, =0 for no sym, -1 for anti-sym).
SYMXY	Symmetry key for aero coordinate x-y plane can be used to simulate ground effects (Integer), same code as SYMXZ.

Remarks:

1. This card is required for aerodynamic problems. Only one AERØ card is allowed.
2. The ACSID must be a rectangular coordinate system. Flow is in the positive x direction.
3. Reference length, b = REFC/2

$$\left(k = \frac{\omega b}{V} \right)$$

BULK DATA DECK

Input Data Card MKAERØ1 Mach Number - Frequency Table

Description: Provides a table of Mach numbers or interblade phase angles (m) and reduced frequencies (k) for aerodynamic matrix calculation.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MKAERØ1	m_1	m_2	m_3	m_4	m_5	m_6	m_7	m_8	ABC
MKAERØ1	.1	.7							+ABC
+BC	k_1	k_2	k_3	k_4	k_5	k_6	k_7	k_8	
+BC	.3	.6	1.0						

Field	Contents
m_i	List of Mach numbers (Real; $1 \leq i \leq 8$).
k_j	List of reduced frequencies (Real > 0.0, $1 \leq j \leq 8$).

Remarks:

1. Blank fields end the list, and thus cannot be used for 0.0.
2. All combinations of (m,k) will be used.
3. The continuation card is required.
4. Since 0.0 is not allowed, it may be simulated with a very small number such as 0.0001.
5. Mach numbers are input for wing flutter and interblade phase angles for blade flutter and response.

Input Data Card MKAERØ2 Mach Number - Frequency Table

Description: Provides a list of Mach numbers or interblade phase angles (m) and reduced frequencies (k) for aerodynamic matrix calculation.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MKAERØ2	m_1	k_1	m_2	k_2	m_3	k_3	m_4	k_4	
MKAERØ2	.10	.30	.10	.60	.70	.30	.70	1.0	

Field Contents

m_i List of Mach numbers (Real > 0.0).

k_i List of reduced frequencies (Real > 0.0).

Remarks:

1. This card will cause the aerodynamic matrices to be computed for a set of parameter pairs.
2. Several MKAERØ2 cards may be in the deck.
3. Imbedded blank pairs are skipped.
4. Mach numbers are input for wing flutter and interblade phase angle for blade flutter and response.

Input Data Card STREAML1 . Blade Streamline Data

Description: Defines grid points on the blade streamline from blade leading edge to blade trailing edge.

Format and Example:

1	2	3	4	5	6	7	8	9	10
STREAML1	SLN	G1	G2	G3	G4	G5	G6	G7	+ABC
STREAML1	3	2	4	6	8	10			

+ABC	G8	G9	-etc-						
+ABC									

Alternate Form:

STREAML1	SLN	GID1	"THRU"	GID2					
STREAML1	5	6	THRU	12					

Field	Contents
SLN	Streamline number (integer > 0).
Gi, GIDi	Grid point identification numbers (integer > 0).

Remarks:

1. This card is required for blade steady aeroelastic, blade flutter, and response problems.

2. There must be one STREAML1 card for each streamline on the blade. For blade dynamic problems, there must be an equal number of STREAML1 and STREAML2 cards.

3. The streamline numbers, SLN, must increase with increasing radial distance of the blade section from the axis of rotation. The lowest and the highest SLN, respectively, will be assumed to represent the blade sections closest to and farthest from the axis of rotation.

4. All grid points should be unique.

5. All grid points referenced by GID1 through GID2 must exist.

6. Each STREAML1 card must have the same number of grid points. The nodes must be input from the blade leading edge to the blade trailing edge in the correct positional order.

Input Data Card STREAML2 Blade Streamline Data

Description: Defines aerodynamic data for a blade streamline.

Format and Example:

STREAML2	SLN	NSTNS	STAGGER	CHORD	RADIUS/ DCBDZB	BSPACE	MACH	DEN	+abc
STREAML2	2	3	23.5	1.85	6.07	.886	.934	.066	

+abc	VEL	FLOWA/ SWEEP							
+ABC	1014.2	55.12							

Field	Contents
SLN	Streamline number (Integer >0)
NSTNS	Number of computing stations on the blade streamline. (3 $\leq$ NSTNS $\leq$ 10, Integer)
STAGGER	Blade stagger angle (-90.0 <stagger <90.0, degrees)
CHORD	Blade chord (real >0.0)
RADIUS/DCBDZB	Radius of streamline for dynamic analysis without sweep effects (real >0.0) or $\partial\bar{C}/\partial\bar{Z}$ for dynamic analysis with sweep effects. $\bar{C}$ is the swept chord and $\bar{Z}$ is the (local) spanwise reference direction (real)
BSPACE	Blade spacing (real >0.0)
MACH	Relative flow mach number at blade leading edge (real >0.0)
DEN	Gas density at blade leading edge (real >0.0)
VEL	Relative flow velocity at blade leading edge (real >0.0)
FLOWA/SWEEP	Relative flow angle at blade leading edge for dynamic analysis without sweep effects (-90.0 <FLOWA <90.0 degrees) or Blade sweep angle for dynamic analysis with sweep effects (-90.0 <SWEEP <90.0 degrees)

Remarks:

1. At least three (3) and no more than fifty (50) STREAML2 cards are required for a blade dynamic analysis.

2. The streamline number, SLN, must be the same as its corresponding SLN on a STREAML1 card. There must be a STREAML1 card for each STREAML2 card.

3. It is not required that all streamlines be used to define the aerodynamic matrices used in blade dynamic analysis.

4. For dynamic analysis with sweep effects, the use of the NASTRAN card is required as follows:

   NASTRAN SYSTEM (93) = 1

   Refer to Section 2.1 of the User's Manual and Section 6.3.1 of the Programmer's Manual for description and placement in the Executive Control Deck.

5. Dynamic analysis refers to both flutter and response analyses.

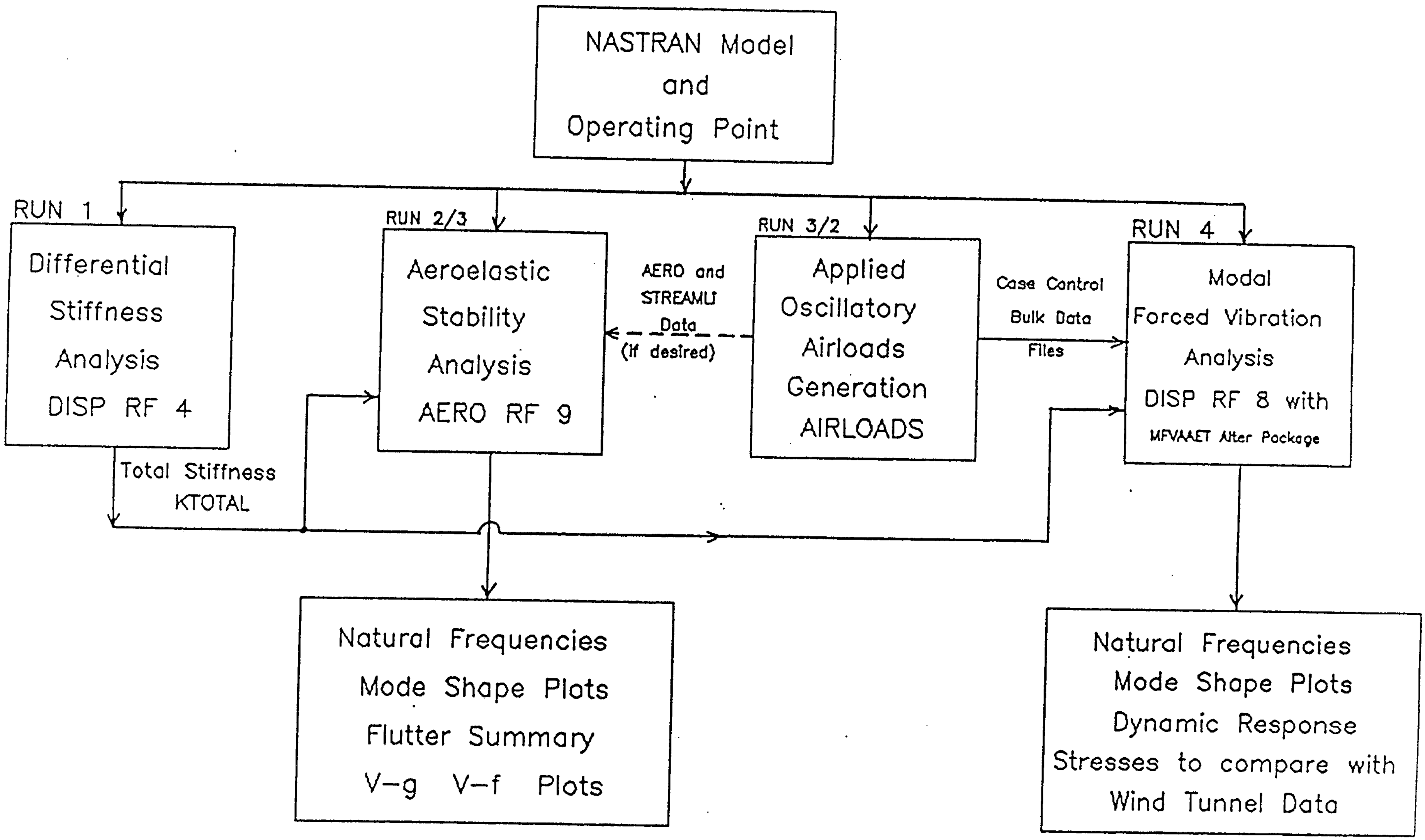


Figure 2.1 Overall Flowchart of Steps to Conduct Modal Forced Vibration Analysis of Aerodynamically Excited Turbosystems

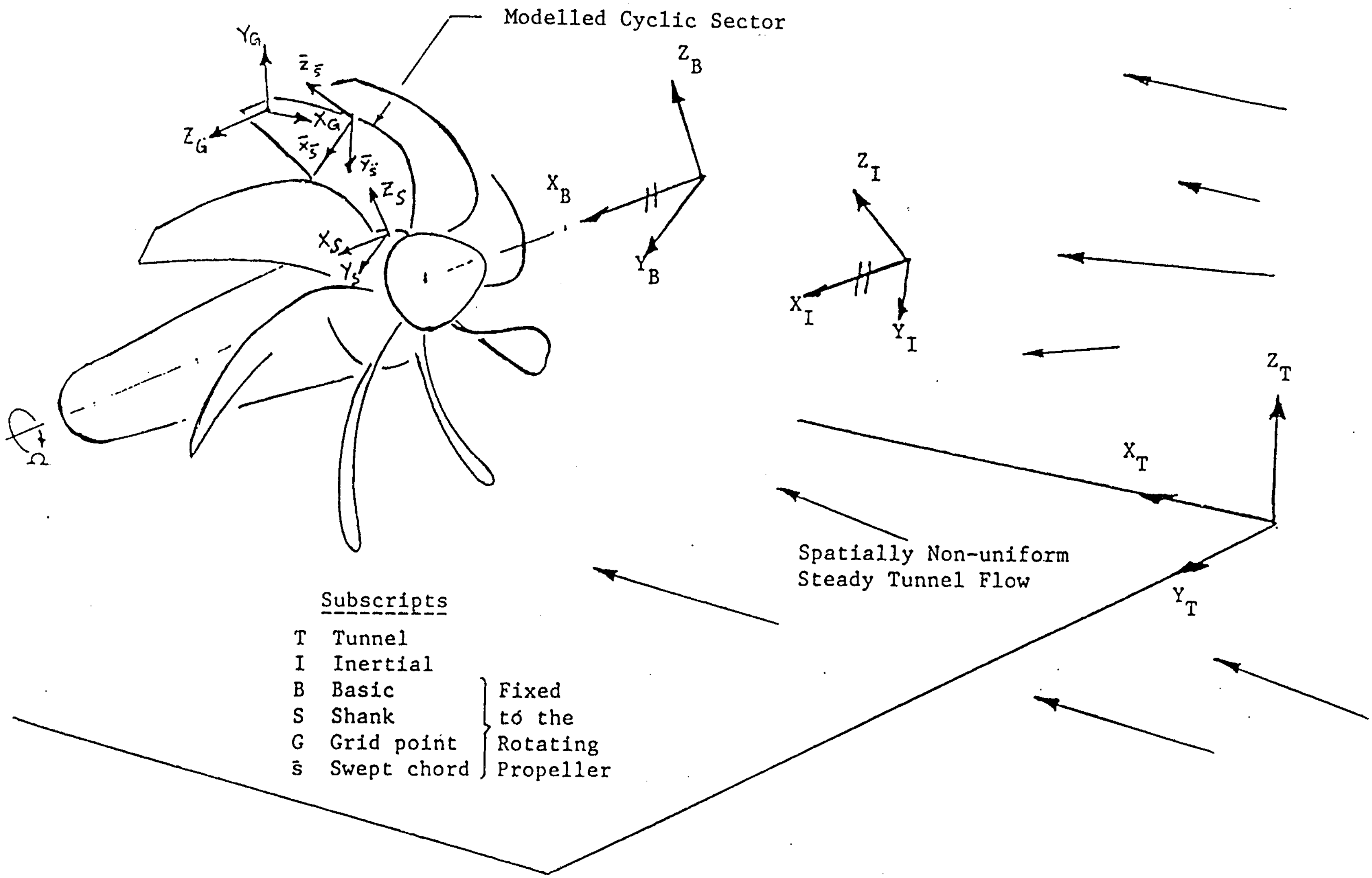


Figure 2.2 Coordinate Systems

NOTES

1. Planes $Z_1Z_2Z_3$ and X_TZ_T need only be parallel to X_IZ_I

2. X_I axis is parallel to Z_3Z_2

3. X_T axis is parallel to Z_1Z_2

4. Uniform Inflow is along $+X_T$

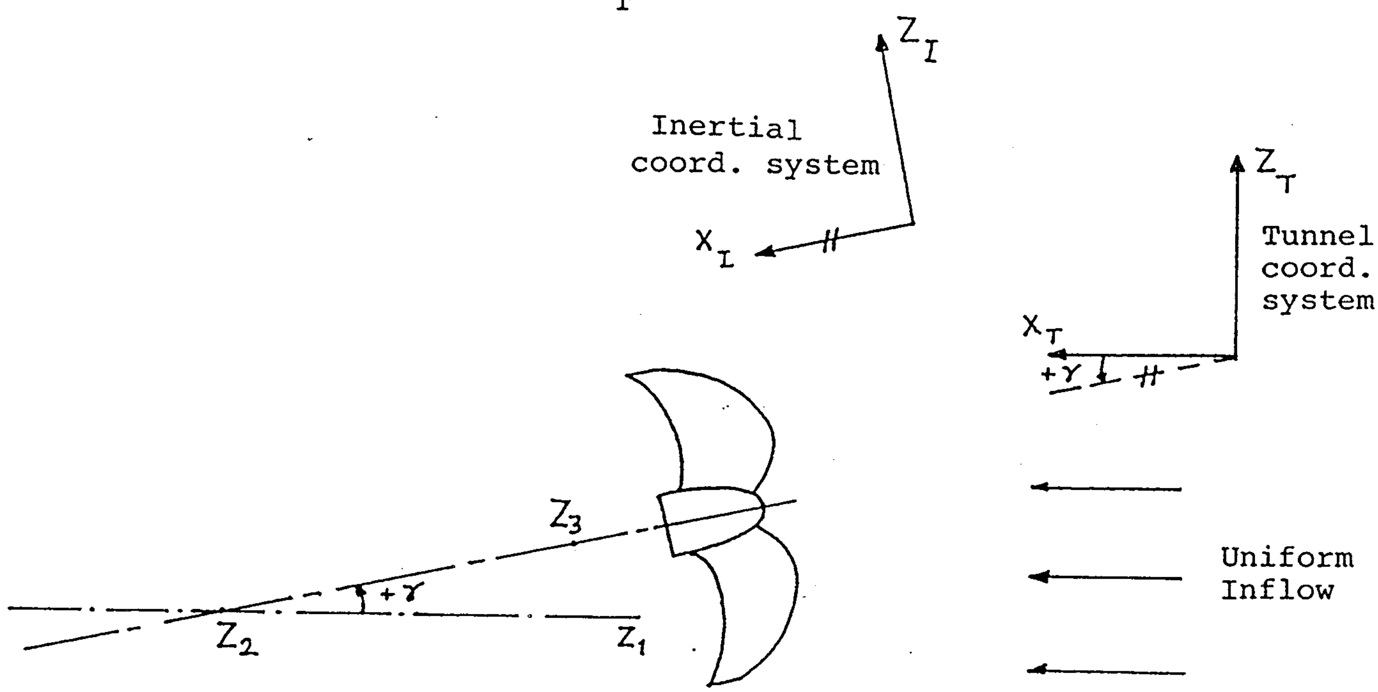
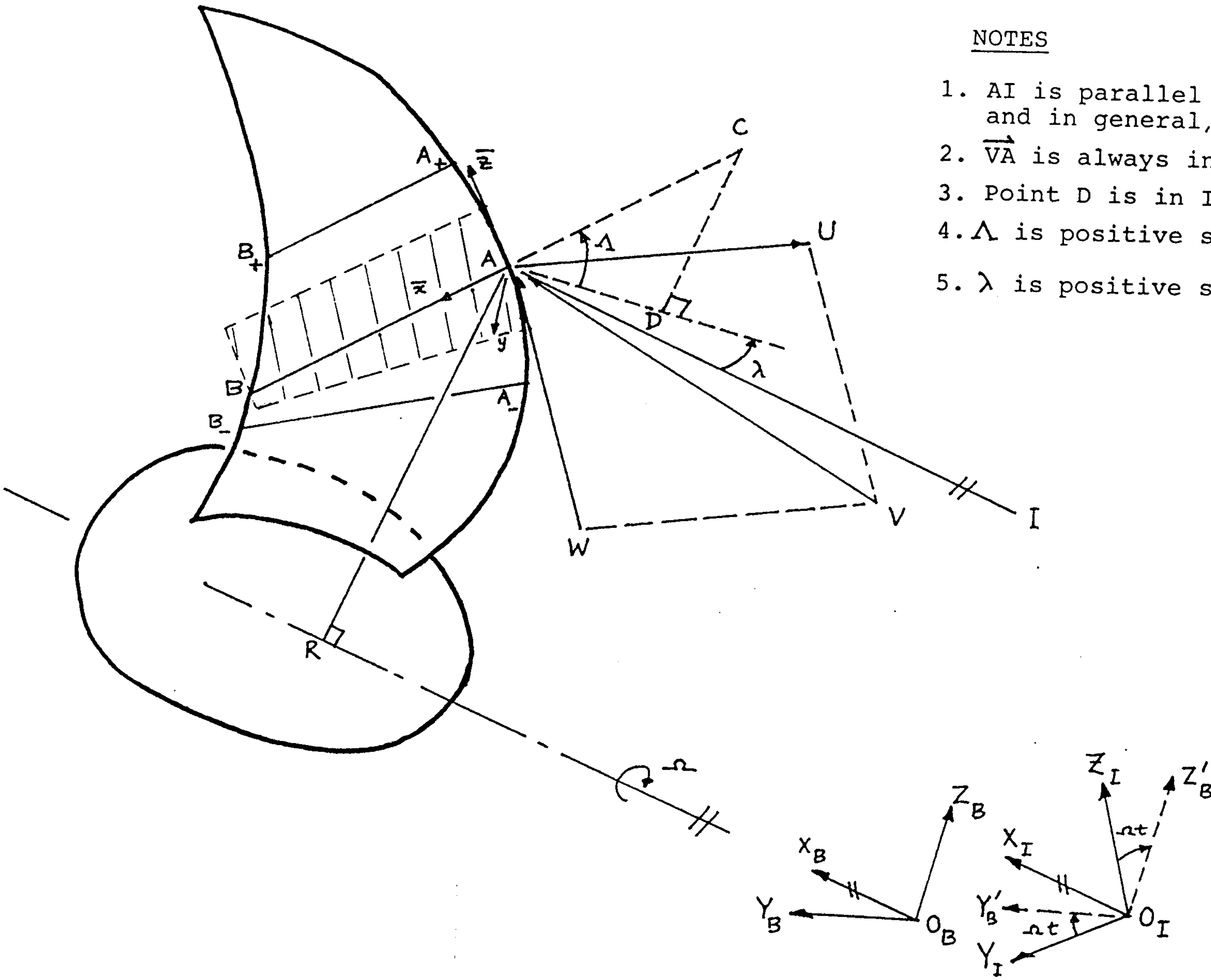


Figure 2.3 Turboprop Axis Inclination Angle and Tunnel Coordinate System Orientation in Uniform Inflow Case



NOTES

1. AI is parallel to axis of rotation, and in general, is NOT in WAU plane
2. $\overrightarrow{VA}$ is always in WAU plane
3. Point D is in IAU plane
4. Λ is positive sweep angle
5. λ is positive stagger angle

Figure 2.4 Some Definitions for Swept Blade Aerodynamics (STREAML2 Bulk Data Card)

SECTION 3

SUPPLEMENT TO
NASTRAN PROGRAMMER'S MANUAL

MODAL FORCED VIBRATION ANALYSIS OF AERODYNAMICALLY EXCITED TURBOSYSTEMS

3.1 INTRODUCTION

The NASTRAN programming effort for conducting modal forced vibration analysis of aerodynamically excited turbosystems involved extensive modifications of, and additions to, the source code in the CRAY version of the April 1984 release of NASTRAN. In addition, the effort also included the adaptation of an existing DMAP ALTER package to this version of NASTRAN, as well as the development of a new DMAP ALTER package.

The above changes fall into two groups. The first group involves changes made in order to incorporate the UNIVAC version of Bladed Shrouded Disks Computer Program enhancements into CRAY NASTRAN. (Complete details of these enhancements are contained in References 3 through 7.). The second group involves changes made in order to incorporate the Updated Bladed Disks Program enhancements developed under the present contract into CRAY NASTRAN.

Details of all of the above changes are discussed in the following subsections.

3.2 UNIVAC TO CRAY CONVERSION OF BLADED DISKS PROGRAM

The incorporation of the UNIVAC version of the Bladed Disks

Program into CRAY involved extensive changes to the CRAY version of April 1984 NASTRAN. These changes are due to the following reasons:

1. Addition of two new bulk data cards:

STREAML1	--	Defines grid points on a blade streamline from the leading edge to the trailing edge
STREAML2	--	Defines aerodynamic data for a blade streamline

2. Addition of the 15 new bulk data parameters (PARAMs):

   APRESS , ATEMP , FXCOOR , FYCOOR , FZCOOR , IREF ,
   KGGIN , KTOUT , MAXMACH, MINMACH, MTYPE , PGEOM ,
   SIGN , STREAML and ZORIGN

3. Addition of four new functional modules:

ALG	--	Aerodynamic load generator
APDB	--	Aerodynamic pool distributor for blades
FVRSTR1	--	Forced vibration response analysis of rotating cyclic structures - Phase 1
FVRSTR2	--	Forced vibration response analysis of rotating cyclic structures - Phase 2

4. Addition of two new rigid formats:

DISP RF 16	--	Static aerothermoelastic analysis with differential stiffness
AERO RF 9	--	Compressor blade cyclic modal flutter analysis

5. Specification of the sweep aerodynamic effects via the NASTRAN card (by specifying the 93rd word of COMMON /SYSTEM/ on the NASTRAN card)

6. Adaptation of a DMAP ALTER package for DISP RF 8 developed for the forced vibration analysis of rotating cyclic structures using the direct approach

7. Various other miscellaneous changes

It is noted here that the addition of the two new rigid formats mentioned above involved not only modifications to the source code, but also expansion of NASTRAN rigid format data base by the

addition of the DMAP sequences and the restart tables for these two new rigid formats.

3.2.1 Modifications to the Source Code

A total of 26 existing subprograms were modified in the UNIVAC to CRAY conversion process. The modified subprograms, the reasons for their modification, and the extent of the changes are summarized in Table 3.1.

The actual changes to the code have been made such that they are easily identified. Thus, lines of code that have been logically deleted have not been physically deleted, but have been commented out by using the string CBELD in columns 1 through 5. Lines of code that have been logically replaced have been commented out by using the string CBELR in columns 1 through 5, with the replacement line (or lines) immediately following the replaced code. New lines added to the code have been bracketed by the comment line CBELNB at the beginning, and the comment line CBELNE at the end of the group of lines added to the code.

3.2.2 Additions to the Source Code

A total of 82 new UNIVAC subprograms were added to CRAY NASTRAN in the conversion process. The added subprograms are identified in Table 3.2.

3.2.3 Adaptation of the DMAP ALTER Package

As part of the UNIVAC version of the Bladed Disks Program, a DMAP ALTER package for DISP RF 8 had been developed for the forced vibration analysis of rotating cyclic structures using the direct approach. This ALTER package was adapted to the CRAY version of April 1984 NASTRAN by changing all the ALTER numbers to correspond to the latest version of DISP RF 8. In addition, the ALTER package was streamlined by making the following changes:

1. All CHKPNT instructions were removed as the already existing PRECHK instruction in the rigid format causes the CHKPNTing of all required data blocks.
2. All SAVE instructions of the form SAVE FLAG were replaced by automatic SAVE features of the form /S,N,FLAG/ in the immediately preceding DMAP instructions.
3. All numerical constant parameters of the form /C,N,M/ were replaced by /M/.
4. All BCD constant parameters of the form /C,N,B/ were replaced by /*B*/.
5. All variable parameters of the form /V,N,VAR/ that were not immediately SAVEd were replaced by /VAR/.

The DMAP ALTER package resulting from the above changes has been named DFVARCS (Direct Forced Vibration Analysis of Rotating Cyclic Structures), and is listed in Table 3.3.

3.3 NEW UPDATES IN BLADED DISKS PROGRAM ON CRAY

These new enhancements also involved extensive changes to the

CRAY version of April 1984 NASTRAN. These changes are primarily due to the following reasons:

1. Development of a new DMAP ALTER package for DISP RF 8 for the forced vibration analysis of aerodynamically excited turbosystems using the modal approach, including the dynamic effects on these rotating cyclic structures.

2. Ability to rearrange, rather than interpolate, the reactionary aerodynamic matrix data in the FRRD2 module in analyses using the newly-developed DMAP ALTER package.

3. Expansion of the CURV and OFP modules to compute and process complex element stresses in material coordinate systems for the CQUAD1/2 and CTRIA1/2 elements.

4. Various other miscellaneous changes.

3.3.1 Modifications to the Source Code

A total of 26 subprograms were modified in order to incorporate the new Updates to the Bladed Disks Program into the CRAY version of April 1984 NASTRAN. The modified subprograms, the reasons for their modification, and the extent of the changes are summarized in Table 3.4.

The actual changes to the code have been made such that they are easily identified. Thus, lines of code that have been logically deleted have not been physically deleted, but have been commented out by using the string CAERD in columns 1 through 5. Lines of code that have been logically replaced have been commented out by using the string CAERR in columns 1 through 5, with the replacement line (or lines) immediately following the

replaced code. New lines added to the code have been bracketed by the comment line CAERNB at the beginning, and the comment line CAERNE at the end of the group of lines added to the code.

3.3.2 Additions to the Source Code

Two new subroutines (OFPCC1 and OFPCC2) were added to the OFP module. These subroutines, in conjunction with the other changes made to the OFP module, are designed to process the complex element stresses in material coordinate systems for the CQUAD1/2 and CTRIA1/2 elements, in both SORT1 and SORT2 output formats.

3.3.3 Development of a New DMAP ALTER Package

As part of the new updates to the Bladed Disks Program, a new DMAP ALTER package for DISP RF 8 was developed for the forced vibration analysis of aerodynamically excited turbosystems using the modal approach. The DMAP ALTER package for DISP RF 8 developed for the direct approach forced vibration analysis of rotating cyclic structures (Table 3.3) was used as the starting point for this effort. This ALTER package was then modified and considerably expanded by making the following major changes:

1. The READ module was added in order to compute the eigenvalues and eigenvectors of rotating cyclic structures. Provision to obtain plots of modal information was made by the inclusion of the CYCT2, SDR1, SDR2 and PLOT modules just after the READ module.

2. The GKAM module was added to generate the modal matrices.

3. The APDB, AMG and AMP modules were inserted in order to generate the reactionary aerodynamic matrix data for subsequent use in the solution phase in the FRRD2 module.

4. Various other changes to the DMAP were made in order to define various control flags and to permit the execution of the solution procedure in an elegant manner.

The DMAP ALTER package resulting from the above changes has been named MFVAAET (Modal Forced Vibration Analysis of Aerodynamically Excited Turbosystems), and is listed in Table 3.5.

A complete listing of the DISP RF 8 Rigid Format as modified by the MFVAAET Alter package is presented in Table 3.6.

TABLE 3.1

CRAY NASTRAN Subprograms Modified to Incorporate

UNIVAC Version of Bladed Disks Program

Subroutine Subprograms (Total: 18)

Subroutine	Reason for modification	Extent of changes
AMG	Extend analysis to compressor blade and swept turboprop blade methods	Moderate
AMPC	Same as AMG	Moderate
CYCT2	Miscellaneous	Moderate
FA2	Miscellaneous	Moderate
FRD2B	Miscellaneous	Minor
FRD2C	Miscellaneous	Minor
IFP	To incorporate two new bulk data cards (STREAML1 and STREAML2)	Moderate
IFPPAR	To incorporate the two new rigid formats (DISP RF 16 and AERO RF 9)	Moderate
IFS3P	Same as IFP	Moderate
NAST01	Miscellaneous	Minor
TTLPGE	To change the title page in order to reflect the current changes	Moderate
XCSA	Same as IFPPAR	Moderate
XLNKDD	To incorporate four new modules (ALG, APDB, FVRSTR1 and FVRSTR2)	Moderate
XMPLDD	Same as XLNKDD	Moderate
XRGDFM	Same as IFPPAR	Moderate
XSEM06	To incorporate the new ALG module into Link 6	Moderate
XSEM07	To incorporate the new FVRSTR1 and FVRSTR2 modules into Link 7	Moderate
XSEM09	To incorporate the new APDB module into Link 9	Moderate

(continued)

TABLE 3.1 (continued)

Block Data Subprograms (Total: 8)

Block data	Reason for modification	Extent of changes
GPTABD	Miscellaneous	Minor
IFX1BD	To incorporate the new STREAML1 and STREAML2 bulk data cards and 15 new bulk data parameters (PARAMs)	Moderate
IFX2BD	To incorporate the new STREAML1 and STREAML2 bulk data cards	Minor
IFX3BD	Same as IFX2BD	Minor
IFX4BD	Same as IFX2BD	Minor
IFX5BD	Same as IFX2BD	Minor
IFX6BD	Same as IFX2BD	Minor
SEMDBD	To permit the addition of the new ALG, APDB, FVRSTR1 and FVRSTR2 modules	Minor

Total Subprograms: 26

TABLE 3.2

New Subprograms Added to CRAY NASTRAN to Incorporate UNIVAC Version of Bladed Disks Program

Subroutine Subprograms (Total: 74)

ALAMDA
AKAPM
AKAPPA
AKP2
AMGB1
AMGB1A
AMGB1B
AMGB1C
AMGB1D
AMGB1S
AMGB2
AMGB2A
AMGT1
AMGT1A
AMGT1B
AMGT1C
AMGT1D
AMGT1S
AMGT1T
AMGT2
AMGT2A
APDB -- Driver for APDB module
APDB1
APDB2
APDB2A
ASYCON
DLKAPM
DRKAPM
FVRST1 -- Driver for FVRSTR1 module
FVRST2 -- Driver for FVRSTR2 module
FVRS1A
FVRS1B
FVRS1C
FVRS1D
FVRS1E
FVRS2A
GAUSS
INTERT
RETNL06 (See Note below)
SUBA
SUBBB
SUBC

(continued)

TABLE 3.2 (continued)

SUBD
UDG1
UD03AN
UD03AP
UD03AR
UD03PB
UD03PO
UD03PR
UD0300 -- Driver for ALG module
UD0301 thru UD0319
UD0325
UD0326
UD0329
UD0330

Function Subprograms (Total: 8)

UDG2 thru UDG9

Total Subprograms: 82

Note: Subroutine RETNL06 is required in order to provide dummy returns for certain subroutines referenced in Link 6.

TABLE 3.3 DMAP ALTER Package DFVARCS

```
ALTER 3 $
FILE      UXVF=APPEND/PDT=APPEND/PD=APPEND $
$ PERFORM INITIAL ERROR CHECKS ON NSEGS AND KMAX.
COND      ERRORC1,NSEGS $  IF USER HAS NOT SPECIFIED NSEGS.
COND      ERRORC1,KMAX  $  IF USER HAS NOT SPECIFIED KMAX.
PARAM     //*EQ*/CYCIOERR /V,Y,CYCIO=0 /0 $
COND      ERRORC1,CYCIOERR  $  IF USER HAS NOT SPECIFIED CYCIO.
PARAM     //*DIV*/NSEG2 /V,Y,NSEGS /2 $  NSEG2 = NSEGS/2
PARAM     //*SUB*/KMAXERR /NSEG2 /V,Y,KMAX $
COND      ERRORC1,KMAXERR $  IF KMAX .GT. NSEGS/2
$ SET DEFAULTS FOR PARAMETERS.
PARAM     //*NOP*/V,Y,NOKPRT=+1 /V,Y,LGKAD=-1 $
$ CALCULATE OMEGA, 2*OMEGA AND OMEGA**2 FROM RPS. SET DEFAULT RPS.
PARAMR    //*MPY*/OMEGA /V,Y,RPS=0.0 /6.283185 $
PARAMR    //*MPY*/OMEGA2 /2.0 /OMEGA $
PARAMR    //*MPY*/OMEGASQR /OMEGA /OMEGA $
$ GENERATE NORPS FLAG IF RPS IS ZERO.
PARAMR    //*EQ*//V,Y,RPS /0.0 ////NORPS $
$ MAKE SURE COUPLED MASSES HAVE NOT BEEN REQUESTED.
PARAM     //*NOT*/NOLUMP /V,Y,COUPMASS=-1 $
COND      ERRORC2,NOLUMP $
ALTER 21,21 $  ADD SLT TO OUTPUT FOR TRLG.
GP3       GEOM3,EQEXIN,GEOM2 / SLT,GPTT / NOGRAV $
ALTER 23 $
$ SINCE MULTIPLE CONSTRAINTS ARE NOT ALLOWED EXECUTE GP4 NOW SO THAT
$ MORE ERROR CHECKS CAN BE MADE BEFORE ELEMENT GENERATION.
$ ADD YS NEEDED FOR PSF RECOVERY IN SSG2.
PARAM     //*MPY*/NSKIP /0/0 $
GP4       CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,/RG,YS,USET,ASET/LUSET/
          S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/S,N,NSKIP/
          S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/S,Y,AUTOSPC $
PURGE     GM,GMD/MPCF1/GO,GOD/OMIT/KFS,PSF,QPC/SINGLE $
$ SUPORT BULK DATA IS NOT ALLOWED.
PARAM     //*NOT*/REACDATA /REACT $
COND      ERRORC3,REACDATA $
$ EXECUTE DPD NOW SO CHECKS CAN BE MADE. ADD TRL TO OUTPUT DATA BLOCKS.
DPD       DYNAMICS,GPL,SIL,USET / GPLD,SILD,USETD,TFPOOL,DLT,PSDL,FRL,,
          TRL,,EQDYN / LUSET/S,N,LUSETD/NOTFL/S,N,NODLT/
          S,N,NOPSDL/S,N,NOFRL/NONLFT/S,N,NOTRL/NOEED//
          S,N,NOUE $
$ MUST HAVE EITHER FREQ OR TSTEP BULK DATA.
PARAM     //*AND*/FTERR /NOFRL /NOTRL $
COND      ERRORC5,FTERR $  NO FREQ OR TSTEP BULK DATA.
$ ONLY FREQUENCY OR TSTEP IS ALLOWED IN THE CASE CONTROL
PARAML    CASECC //*DTI*/1/14//FREQSET $
PARAML    CASECC //*DTI*/1/38//TIMESET $
PARAM     //*MPY*/FREQTIME /FREQSET /TIMESET $
PARAM     //*NOT*/FTERR1 /FREQTIME $
PARAM     //*LE*/NOFREQ /FREQSET /0 $
PARAM     //*LE*/NOTIME /TIMESET /0 $
COND      ERRORC6,FTERR1 $  BOTH FREQ AND TSTEP IN CASE CONTROL DECK.
$ EPOINT BULK DATA NOT ALLOWED
PARAM     //*NOT*/EXTRAPTS /NOUE $
COND      ERRORC4,EXTRAPTS $
$ GENERATE DATA FOR CYCT2 MODULE.
GPCYC     GEOM4,EQDYN,USETD /CYCDD /CTYPE=ROT /S,N,NOGO $
COND      ERRORC1,NOGO $
```

```
ALTER 33 $
$ PRE-PURGE DATA BLOCKS THAT WILL NOT BE GENERATED
PARAM    //*OR*/NOBM1 /NOMGG /NORPS $
PURGE    B1GG,M1GG /NOBM1 $
PURGE    M2GG,M2BASEXG /NOMGG $
ALTER 36 $
$ GENERATE DATA BLOCKS FRLX, B1GG, M1GG, M2GG AND BASEGX.
$ GENERATE PARAMETERS FKMAX AND NOBASEX.
FVRSTR1  CASECC,BGPDT,CSTM,DIT,FRL,MGG,, / FRLX,B1GG,M1GG,
         M2GG,BASEXG,PDZERO,, /NOMGG/V,Y,CYCIO/V,Y,NSEGS/
         V,Y,KMAX/S,N,FKMAX/V,Y,BXTID=-1/V,Y,BXPTID=-1/
         V,Y,BYTID=-1/V,Y,BYPTID=-1/V,Y,BZTID=-1/
         V,Y,BZPTID=-1/S,N,NOBASEX/NOFREQ/OMEGA  $
PARAML   FRLX //*PRESENCE*////NOFRLX $
COND     LBLFRLX,NOFRLX $
EQUIV    FRLX,FRL $
LABEL    LBLFRLX $
ALTER 43 $
PARAM    //*ADD*/NOBGG /NOBM1 /0 $  RESET NOBGG.
ALTER 53 $
$ REDEFINE BGG AND KGG.
COND     LBL11A,NOBM1 $
PARAMR   //*COMPLEX*// OMEGA2 /0.0/ CMPLX1 $
PARAMR   //*SUB*/ MOMEGASQ / 0.0 / OMEGASQR $
PARAMR   //*COMPLEX*// MOMEGASQ / 0.0 / CMPLX2 $
ADD      BGG,B1GG / BGG1 / (1.0,0.0) / CMPLX1 $
EQUIV    BGG1,BGG $
ADD      KGG,M1GG / KGG1 / (1.0,0.0) / CMPLX2 $
EQUIV    KGG1,KGG $
LABEL    LBL11A
ALTER 54,56 $ GP4 HAS BEEN MOVED-UP.
ALTER 88,88 $ DPD HAS BEEN MOVED-UP.
ALTER 113 $  PARAM AND EQUIV LOGIC DEPENDING ON LGKAD FOR FREQ OR TRAN.
PARAM    //*AND*/KDEKA/NOUE/NOK2PP $
COND     LGKAD1,LGKAD $  BRANCH IN NOT FREQRESP.
ALTER 114 $  SEE ALTER 113 COMMENT.
JUMP     LGKAD2 $
LABEL    LGKAD1 $
EQUIV    M2PP,M2DD/NOA/B2PP,B2DD/NOA/K2PP,K2DD/NOA/MAA,MDD/MDEMA/
         KAA,KDD/KDEKA $
LABEL    LGKAD2 $
ALTER 116,116 $ ADD PARAMETERS GKAD, W3 AND W4 TO GKAD.
GKAD     USETD,GM,GO,KAA,BAA,MAA,K4AA,K2PP,M2PP,B2PP/KDD,BDD,MDD,GMD,
         GOD,K2DD,M2DD,B2DD/C,Y,GKAD=TRANRESP/*DISP*/*DIRECT*/
         C,Y,G=0.0/C,Y,W3=0.0/C,Y,W4=0.0/NOK2PP/NOM2PP/
         NOB2PP/MPCF1/SINGLE/OMIT/NOUE/NOK4GG/
         NOBGG/KDEK2/-1 $
ALTER 117 $  SEE ALTER 113 COMMENT.
COND     LGKAD3,LGKAD $  BRANCH IF NOT FREQRESP.
ALTER 118 $  SEE ALTER 113 COMMENT.
JUMP     LGKAD4 $
LABEL    LGKAD3 $
EQUIV    B2DD,BDD/NOGPDT/M2DD,MDD/NOSIMP/K2DD,KDD/KDEK2 $
LABEL    LGKAD4 $
ALTER 119,123 $
$ NEW SOLUTION LOGIC
$ GENERATE TIME-DEPENDENT LOADS IF TSTEP WAS REQUESTED IN CASE CONTROL.
$ USE FOL INSTEAD OF PPF TO GET OUTPUT FREQUENCY LIST.
COND     LBLTRL1,NOTIME $
$ LOOP THRU ALL SUBCASES FOR TIME-DEPENDENT LOADS.
PARAM    //*MPY*/REPEATT /1 /-1 $
PARAM    //*ADD*/APPFLG /1 /0 $  INITIALIZE FOR SDR1.
LABEL    TRLGLOOP $
CASE     CASECC,/CASEYY/*TRAN*/S,N,REPEATT/S,N,NOLOOP1 $
PARAM    //*MPY*/NCOL /0 /1 $
TRLG     CASEYY,USETD,DLT,SLT,BGPDT,SIL,CSTM,TRL,DIT,GMD,GOD,,EST,MGG/
```

```
            ,,PDT1,PD1,,TOL/ NOSET/NCOL $
SDR1        TRL,PDT1,,,,,,,,, / ,PDT, /APPFLG/*DYNAMICS* $
SDR1        TRL,PD1 ,,,,,,,,, / ,PD , /APPFLG/*DYNAMICS* $
PARAM       //*ADD*/APPFLG /APPFLG /1 $  APPFLG=APPFLG+1.
COND        TRLGDONE,REPEATT $
REPT        TRLGLOOP,100 $
JUMP        ERROR3 $
LABEL       TRLGDONE $
FVRSTR2     TOL,,,,,,, / FRLZ,FOLZ,REORDER1,REORDER2,,,, /
            V,Y,NSEGS/V,Y,CYCIO/S,Y,LMAX=-1/FKMAX/
            S,N,FLMAX/S,N,NTSTEPS/S,N,NORO1/S,N,NORO2 $
EQUIV       FRLZ,FRL // FOLZ,FOL $
JUMP        LBLFRL2 $
LABEL       LBLTRL1 $
$ GENERATE FREQUENCY-DEPENDENT LOADS IF FREQUENCY WAS SELECTED IN CC.
FRLG        CASEXX,USETD,DLT,FRL,GMD,GOD,DIT, / PPF,PSF,PDF,FOL,PHFDUM /
            *DIRECT*/FREQY/*FREQ* $
COND        LBLFRLX1,NOFRLX $  ZERO OUT LOAD COLUMNS IF FRLX WAS GENERATED.
MPYAD       PPF,PDZERO, / PPFX /0 $
EQUIV       PPFX,PPF $
LABEL       LBLFRLX1 $
$ FORM NEW LOADS.
COND        LBLFRL1,NOBASEX $
MPYAD       M2GG,BASEXG, / M2BASEXG /0 $
ADD         PPF,M2BASEXG / PPF1 /(1.0,0.0) /(-1.0,0.0) $
EQUIV       PPF1,PPF $
COND        LBLBASE1,NOSET $
SSG2        USETD,GMD,YS,KFS,GOD,,PPF / ,PODUM1,PSF1,PDF1 $
EQUIV       PSF1,PSF // PDF1,PDF $
LABEL       LBLBASE1 $
LABEL       LBLFRL1 $
EQUIV       PPF,PDF/NOSET $
$ LOADS ARE FREQUENCY-DEPENDENT
$ PERFORM CYCLIC TRANSFORMATION ON LOADS IF CYCIO=+1.
PARAML      PDF //*TRAILER*/1 /PDFCOLS $
$ CALCULATE THE NUMBER OF LOADS FOR CYCIO=-1.
PARAM       //*DIV*/NLOAD /PDFCOLS /FKMAX $ NLOAD = NF/FKMAX
EQUIV       PDF,PXF/CYCIO $
COND        LBLPDONE,CYCIO $
$ CALCULATE THE NUMBER OF LOADS FOR CYCIO=1.
PARAM       //*DIV*/NLOAD /PDFCOLS /V,Y,NSEGS $ NLOAD = NF/NSEGS
CYCT1       PDF / PXF,GCYCF1 /CTYPE /*FORE*/V,Y,NSEGS=-1 /
            V,Y,KMAX=-1 / NLOAD /S,N,NOGO $
COND        ERRORC1,NOGO $
JUMP        LBLPDONE $
LABEL       LBLFRL2 $
$ LOADS ARE TIME-DEPENDENT
PARAM       //*NOT*/NOTCYCIO /V,Y,CYCIO $
$ BRANCH DEPENDING ON VALUE OF CYCIO
COND        LBLTRL2,NOTCYCIO $
$ CYCIO=-1
EQUIV       PD,PDTRZ1/NORO1 $
COND        LBLRO1A,NORO1 $
MPYAD       PD,REORDER1, / PDTRZ1 / 0 $
LABEL       LBLRO1A $
CYCT1       PDTRZ1 / PXTRZ1,GCYCF2 /CTYPE/*FORE*/NTSTEPS/
            V,Y,LMAX/FKMAX/S,N,NOGO $
COND        ERRORC1,NOGO $
EQUIV       PXTRZ1,PXFZ1/NORO2 $
COND        LBLRO2A,NORO2 $
MPYAD       PXTRZ1,REORDER2, / PXFZ1 /0 $
LABEL       LBLRO2A $
EQUIV       PXFZ1,PXF1 $
JUMP        LBLTRL3 $
LABEL       LBLTRL2 $
$ CYCIO = +1
```

```
MPYAD     PD,REORDER1, / PDTRZ2 / 0 $
CYCT1     PDTRZ2 /PXTRZ2,GCYCF3 /CTYPE/*FORE*/NTSTEPS/V,Y,LMAX/
          V,Y,NSEGS/S,N,NOGO $
COND      ERRORC1,NOGO $
EQUIV     PXTRZ2,PXTR2/NORO2 $
COND      LBLRO2B,NORO2 $
MPYAD     PXTRZ2,REORDER2, / PXTR2 /0 $
LABEL     LBLRO2B $
CYCT1     PXTR2 / PXFZ2,GCYCF4 / CTYPE/*FORE*/V,Y,NSEGS/V,Y,KMAX/
          FLMAX/S,N,NOGO $

COND      ERRORC1,NOGO $
EQUIV     PXFZ2,PXF1 $
LABEL     LBLTRL3 $
$ TIME-DEPENDENT LOADS ARE REAL. MAKE LOADS COMPLEX TO CORRESPOND
$ TO FREQUENCY DEPENDENT LOADS. ALSO SDR2 EXPECTS LOADS TO BE COMPLEX
$ IN FREQRESP TYPE PROBLEMS.
COPY      PXF1 / PXF2  $  CONVERT REAL PXF1 TO COMPLEX PXF.
ADD       PXF1,PXF2 / PXF / (0.5,1.0) / (0.5,-1.0) $
$ DEFINE NLOAD FOR CYCT2.
PARAM     //*ADD*/NLOAD /FLMAX /0 $  NLOAD = FLMAX
LABEL     LBLPDONE $
PARAM     //*ADD*/KINDEX /V,Y,KMIN=0 /0 $  INTITIALIZE KINDEX.
$
$ INITIALIZE UXVF IF KMIN IS NOT ZERO.
$
PARAM     //*ADD*/KMINL /V,Y,KMIN /-1 $
COND      NOKMINL,KMINL $
PARAM     //*ADD*/KMINV /0 /0 $
LABEL     KMINLOOP $
CYCT2     CYCDD,,,PXF,, /,,PKFZ,, /*FORE*/V,Y,NSEGS/
          KMINV/CYCSEQ/NLOAD/S,N,NOGO $
COND      ERRORC1,NOGO $
ADD       PKFZ, / UKVFZ / (0.0,0.0) $
PRTPARM   //0/*KINDEX* $
CYCT2     CYCDD,,,UKVFZ,, /,,UXVF,, /*BACK*/V,Y,NSEGS/
          KMINV/CYCSEQ/NLOAD/S,N,NOGO $
PRTPARM   //0/*KINDEX* $
COND      ERRORC1,NOGO $
PARAM     //*ADD*/KMINV /KMINV /1 $
REPT      KMINLOOP,KMINL $
LABEL     NOKMINL $
LABEL     TOPCYC $  LOOP ON KINDEX
COND      NOKPRT,NOKPRT $
PRTPARM   //0 /*KINDEX* $
LABEL     NOKPRT $
CYCT2     CYCDD,KDD,MDD,,, /KKKF,MKKF,,, /*FORE*/V,Y,NSEGS /
          KINDEX/CYCSEQ=-1/NLOAD/S,N,NOGO $
COND      ERRORC1,NOGO $
CYCT2     CYCDD,BDD,,PXF,, /BKKF,,PKF,, /*FORE*/V,Y,NSEGS/
          KINDEX/CYCSEQ/NLOAD/S,N,NOGO $
COND      ERRORC1,NOGO $
$ SOLUTION
FRRD2     KKKF,BKKF,MKKF,,PKF,FOL / UKVF /0.0/0.0/-1.0 $
CYCT2     CYCDD,,,UKVF,, /,,UXVF,, /*BACK*/V,Y,NSEGS/KINDEX/
          CYCSEQ/NLOAD/S,N,NOGO $
COND      ERRORC1,NOGO $
PARAM     //*ADD*/KINDEX/KINDEX/1 $  KINDEX = KINDEX + 1
PARAM     //*SUB*/DONE / V,Y,KMAX / KINDEX $
COND      LCYC2,DONE $  IF KINDEX .GT. KMAX THEN EXIT
REPT      TOPCYC,100 $
JUMP      ERROR3 $
LABEL     LCYC2 $
EQUIV     UXVF,UDVF / CYCIO $
COND      LCYC3,CYCIO $  IF CYCIO .GE. 0 THEN TRANSFORM TO PHYSICAL.
CYCT1     UXVF / UDVF,GCYCB1 / CTYPE/*BACK*/V,Y,NSEGS/V,Y,KMAX/
```

```
         NLOAD $
LABEL    LCYC3 $
COND     LBLTRL4,NOTIME $
EQUIV    PXF,PDF2 / CYCIO $
COND     LCYC4,CYCIO $  IF CYCIO .GE. 0 THEN TRANSFORM TO PHYSICAL.
CYCT1    PXF / PDF2,GCYCB2 / CTYPE/*BACK*/V,Y,NSEGS/V,Y,KMAX/
         NLOAD $
LABEL    LCYC4 $
$ IF LOADS WERE TIME-DEPENDENT THEN RECOVER PPF AND PSF FROM PXF.
SDR1     USETD,,PDF2,,,GOD,GMD,,,, / PPFZ,, /1 /*DYNAMICS* $
SSG2     USETD,GMD,YS,KFS,GOD,,PPFZ / ,PODUM,PSFZ,PLDUM $
EQUIV    PPFZ,PPF // PSFZ,PSF $
LABEL    LBLTRL4 $
VDR      CASEXX,EQDYN,USETD,UDVF,FOL,XYCDB,/OUDVC1,/*FREQRESP*/
         *DIRECT*/S,N,NOSORT2/S,N,NOD/S,N,NOP/0 $
ALTER 139,139 $  USE FOL INSTEAD OF PPF TO GET OUTPUT FREQUENCY LIST.
SDR2     CASEXX,CSTM,MPT,DIT,EQDYN,SILD,,,BGPDP,FOL,QPC,UPVC,EST,XYCDB,
         PPF/OPPC1,OQPC1,OUPVC1,OESC1,OEFC1,PUPVC1/*FREQRESP*/
         S,N,NOSORT2 $
ALTER 161   $  ADD LABEL FOR ERROR3.
LABEL    ERROR3 $
ALTER 164,167 $  REMOVE ERROR1 AND ERROR2.
ALTER 169 $ FORCED VIBRATION ERRORS
LABEL    ERRORC1 $  CHECK NSEGS, KMAX AND OTHER CYCLIC DATA.
PRTPARM  //-7 /*CYCSTATICS* $
LABEL    ERRORC2 $  COUPLED MASS NOT ALLOWED.
PRTPARM  //0 /C,Y,COUPMASS $
JUMP     FINIS $
LABEL    ERRORC3 $  SUPORT BULK DATA NOT ALLOWED.
PRTPARM  //-6 /*CYCSTATICS* $
LABEL    ERRORC4 $  EPOINT BULK DATA NOT ALLOWED.
PRTPARM  //0 /*NOUE* $
JUMP     FINIS $
LABEL    ERRORC5 $  NEITHER FREQ OR TSTEP WERE IN BULK DATA DECK.
PRTPARM  //0 /*NOFRL* $
PRTPARM  //0 /*NOTRL* $
JUMP     FINIS $
LABEL    ERRORC6 $  BOTH FREQ AND TSTEP WERE SELECTED IN CASE CONTROL.
PRTPARM  //0 /*NOFREQ* $
PRTPARM  //0 /*NOTIME* $
ENDALTER $
```

TABLE 3.4

CRAY NASTRAN Subprograms Modified to Incorporate

Updated Bladed Disks Program

Subroutine Subprograms (Total: 23)

Subroutine	Reason for modification	Extent of changes
APDB	To permit the FLIST data block to be purged if the approach is not AERO	Moderate
CURV	To give better diagnostics	Minor
CURV1	To permit the computation of complex element stresses in material coordinate systems for the CQUAD1/2 and CTRIA1/2 elements	Moderate
CURV2	Same as CURV1 as well as to correct a problem with the handling of incoming stresses/strains when the number of frequencies, times or subcases involved is more than one	Extensive
CYCT2A	To correctly write a matrix trailer	Minor
FRD2I	To avoid interpolation and and to permit just rearrangement of the QHHL data in the FRRD2 module when the third parameter is specified as a negative number	Extensive
FVRST1	To set the Coriolis acceleration coefficient matrix and the base acceleration coeffi-matrix as square matrices rather than as square symmetric matrices	Minor
OFP	To process complex element stresses in material coordinate systems for the CQUAD1/2 and CTRIA1/2 elements in both SORT1 and SORT2 output formats	Moderate
OFP1A	Same as OFP	Moderate

(continued)

TABLE 3.4 (continued)

Subroutine	Reason for modification	Extent of changes
SDR3A	To permit transformation of data from SORT1 format to SORT2 format when the number of frequencies, times or subcases involved is one	Minor
AMGB1B GAUSS	To improve unsteady pressure calculations in subsonic aero-dynamics without sweep effects	Minor
AMGB1C	To rectify and rearrange AJJ computations in supersonic aerodynamics without sweep effects	Extensive
AMGT1B	To improve unsteady pressure calculations in subsonic aerodynamics with sweep effects	Minor
AMGT1 AMGT1A AMGT1C AMGT1T SUBA SUBBB SUBC SUBD	To incorporate sweep effects in supersonic aerodynamics	Extensive
AMGT1D	To permit interpolation of transonic aerodynamic matrices from subsonic and supersonic matrices with sweep effects	Moderate

(continued)

TABLE 3.4 (continued)

Block Data Subprograms (Total: 3)

Block data	Reason for modification	Extent of changes
OFP1BD	To process complex element stresses in material coordinate systems for the CQUAD1/2 and CTRIA1/2 elements in both SORT1 and SORT2 output formats	Moderate
OF2PBD	To correct the output heading of complex element stresses in element coordinate systems for CTRIA2 elements in SORT1 format	Minor
SEMDBD	To permit the processing of larger DMAPs than was possible earlier	Minor

Total Subprograms: 26

Note: Subroutines APDB, FVRST1, AMGB1B, GAUSS, AMGB1C, AMGT1B, AMGT1, AMGT1A, AMGT1C, AMGT1T, SUBA, SUBBB, SUBC, SUBD and AMGT1D mentioned above were added to the code as part of the UNIVAC version of the Bladed Disks Program (see Table 3.2). The rest of the subprograms existed in CRAY April 1984 NASTRAN.

TABLE 3.5 DMAP ALTER Package MFVAAET

```
ALTER 3 $
FILE      UXVF=APPEND/PDT=APPEND/PD=APPEND $
$ PERFORM INITIAL ERROR CHECKS ON NSEGS, KMAX, KMIN AND KINDEX.
COND      ERRORC1,NSEGS $  IF USER HAS NOT SPECIFIED NSEGS.
COND      ERRORC1,KMAX  $  IF USER HAS NOT SPECIFIED KMAX.
COND      ERRORC1,KMIN  $  IF USER HAS SPECIFIED NEGATIVE KMIN.
PARAM     //*NE*/KTEST/V,Y,KMAX/V,Y,KMIN=0 $
COND      LBL1KIND,KTEST $
$ KMIN = KMAX
PARAM     //*ADD*/KINDEX/V,Y,KMAX/0  $  SET KINDEX = KMAX (= KMIN)
JUMP      LBL2KIND $
LABEL     LBL1KIND
$ KMIN .NE. KMAX
COND      ERRORC1,KINDEX  $  IF USER HAS NOT SPECIFIED KINDEX.
PARAM     //*LT*/KTEST/V,Y,KINDEX/V,Y,KMIN $
COND      ERRORC1,KTEST $
PARAM     //*GT*/KTEST/V,Y,KINDEX/V,Y,KMAX $
COND      ERRORC1,KTEST $
LABEL     LBL2KIND $
PARAM     //*EQ*/CYCIOERR /V,Y,CYCIO=0 /0 $
COND      ERRORC1,CYCIOERR  $  IF USER HAS NOT SPECIFIED CYCIO.
PARAM     //*DIV*/NSEG2 /V,Y,NSEGS /2 $  NSEG2 = NSEGS/2
PARAM     //*SUB*/KMAXERR /NSEG2 /V,Y,KMAX $
COND      ERRORC1,KMAXERR $  IF KMAX .GT. NSEGS/2
$ CHECK FOR KINDEX = 0
PARAM     //*EQ*/KTEST/V,Y,KINDEX/0 $
COND      LBL3KIND,KTEST $
$ CHECK FOR KINDEX = NSEGS/2 (NSEGS EVEN ONLY)
PARAM     //*ADD*/NSEGS1/V,Y,NSEGS/1 $
PARAM     //*DIV*/NSEG21/NSEGS1/2 $
PARAM     //*EQ*/KEVEN/NSEG21/NSEG2 $
PARAM     //*EQ*/KNSEG2/NSEG2/V,Y,KINDEX $
PARAM     //*EQ*/KTEST/KNSEG2/KEVEN $
COND      LBL3KIND,KTEST $
$ KINDEX IS .NE.0 AND .NE. NSEGS/2 (NSEGS EVEN ONLY)
PARAM     //*ADD*/KTEST/1/0 $
LABEL     LBL3KIND $
PARAM     //*GT*/KFLAG/KTEST/0 $
$ SET DEFAULTS FOR PARAMETERS.
PARAM     //*NOP*/V,Y,NOKPRT=+1 /V,Y,LGKAD=-1 $
$ CALCULATE OMEGA, 2*OMEGA AND OMEGA**2 FROM RPS. SET DEFAULT RPS.
PARAMR    //*MPY*/OMEGA /V,Y,RPS=0.0 /6.283185 $
PARAMR    //*MPY*/OMEGA2 /2.0 /OMEGA $
PARAMR    //*MPY*/OMEGASQR /OMEGA /OMEGA $
$ GENERATE NORPS FLAG IF RPS IS ZERO.
PARAMR    //*EQ*//V,Y,RPS /0.0 ////NORPS $
$ MAKE SURE COUPLED MASSES HAVE NOT BEEN REQUESTED.
PARAM     //*NOT*/NOLUMP /V,Y,COUPMASS=-1 $
COND      ERRORC2,NOLUMP $
ALTER 21,21 $  ADD SLT TO OUTPUT FOR TRLG.
GP3       GEOM3,EQEXIN,GEOM2 / SLT,GPTT / NOGRAV $
ALTER 23 $
$ SINCE MULTIPLE CONSTRAINTS ARE NOT ALLOWED EXECUTE GP4 NOW SO THAT
$ MORE ERROR CHECKS CAN BE MADE BEFORE ELEMENT GENERATION.
$ ADD YS NEEDED FOR PSF RECOVERY IN SSG2.
PARAM     //*MPY*/NSKIP /0/0 $
```

```
GP4      CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,/RG,YS,USET,ASET/LUSET/
         S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/S,N,NSKIP/
         S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/S,Y,AUTOSPC $
PURGE    GM,GMD/MPCF1/GO,GOD/OMIT/KFS,PSF,QPC/SINGLE $
$ SUPORT BULK DATA IS NOT ALLOWED.
PARAM    //*NOT*/REACDATA /REACT $
COND     ERRORC3,REACDATA $
$ EXECUTE DPD NOW SO CHECKS CAN BE MADE. ADD TRL TO OUTPUT DATA BLOCKS.
DPD      DYNAMICS,GPL,SIL,USET / GPLD,SILD,USETD,TFPOOL,DLT,PSDL,FRL,,
         TRL,EED,EQDYN / LUSET/S,N,LUSETD/NOTFL/S,N,NODLT/
         S,N,NOPSDL/S,N,NOFRL/NONLFT/S,N,NOTRL/S,N,NOEED//
         S,N,NOUE $
$ CHECK FOR EIGENVALUE EXTRACTION DATA
COND     ERRORC7,NOEED $
$ MUST HAVE EITHER FREQ OR TSTEP BULK DATA.
PARAM    //*AND*/FTERR /NOFRL /NOTRL $
COND     ERRORC5,FTERR $  NO FREQ OR TSTEP BULK DATA.
$ ONLY FREQUENCY OR TSTEP IS ALLOWED IN THE CASE CONTROL
PARAML   CASECC //*DTI*/1/14//FREQSET $
PARAML   CASECC //*DTI*/1/38//TIMESET $
PARAM    //*MPY*/FREQTIME /FREQSET /TIMESET $
PARAM    //*NOT*/FTERR1 /FREQTIME $
PARAM    //*LE*/NOFREQ /FREQSET /0 $
PARAM    //*LE*/NOTIME /TIMESET /0 $
COND     ERRORC6,FTERR1 $  BOTH FREQ AND TSTEP IN CASE CONTROL DECK.
$ EPOINT BULK DATA NOT ALLOWED
PARAM    //*NOT*/EXTRAPTS /NOUE $
COND     ERRORC4,EXTRAPTS $
$ GENERATE DATA FOR CYCT2 MODULE.
GPCYC    GEOM4,EQDYN,USETD /CYCDD /CTYPE=ROT /S,N,NOGO $
COND     ERRORC1,NOGO $
ALTER 28 $
PARAM    //*NOP*/V,Y,KGGIN=-1 $
COND     JMPKGGIN,KGGIN $
PARAM    //*ADD*/NOKGGX/-1/0 $
INPUTT1  /KTOTAL,,,,/C,Y,LOCATION=-1/C,Y,INPTUNIT=0 $
EQUIV    KTOTAL,KGGX $
LABEL    JMPKGGIN $
ALTER 33 $
$ PRE-PURGE DATA BLOCKS THAT WILL NOT BE GENERATED
PARAM    //*OR*/NOBM1 /NOMGG /NORPS $
PURGE    B1GG,M1GG /NOBM1 $
PURGE    M2GG,M2BASEXG /NOMGG $
ALTER 36 $
$ GENERATE DATA BLOCKS FRLX, B1GG, M1GG, M2GG AND BASEGX.
$ GENERATE PARAMETERS FKMAX AND NOBASEX.
FVRSTR1  CASECC,BGPDT,CSTM,DIT,FRL,MGG,, / FRLX,B1GG,M1GG,
         M2GG,BASEXG,PDZERO,, /NOMGG/V,Y,CYCIO/V,Y,NSEGS/
         V,Y,KMAX/S,N,FKMAX/V,Y,BXTID=-1/V,Y,BXPTID=-1/
         V,Y,BYTID=-1/V,Y,BYPTID=-1/V,Y,BZTID=-1/
         V,Y,BZPTID=-1/S,N,NOBASEX/NOFREQ/OMEGA   $
PARAML   FRLX //*PRESENCE*////NOFRLX $
COND     LBLFRLX,NOFRLX $
EQUIV    FRLX,FRL $
LABEL    LBLFRLX $
ALTER 43 $
PARAM    //*ADD*/NOBGG /NOBM1 /0 $  RESET NOBGG.
ALTER 53 $
$ REDEFINE BGG AND KGG.
COND     LBL11A,NOBM1 $
PARAMR   //*COMPLEX*// OMEGA2 /0.0/ CMPLX1 $
PARAMR   //*SUB*/ MOMEGASQ / 0.0 / OMEGASQR $
PARAMR   //*COMPLEX*// MOMEGASQ / 0.0 / CMPLX2 $
ADD      BGG,B1GG / BGG1 / (1.0,0.0) / CMPLX1 $
EQUIV    BGG1,BGG $
ADD      KGG,M1GG / KGG1 / (1.0,0.0) / CMPLX2 $
```

```
EQUIV    KGG1,KGG $
LABEL    LBL11A
ALTER 54,56 $ GP4 HAS BEEN MOVED-UP.
ALTER 88,88 $ DPD HAS BEEN MOVED-UP.
ALTER 113 $  PARAM AND EQUIV LOGIC DEPENDING ON LGKAD FOR FREQ OR TRAN.
PARAM    //*AND*/KDEKA/NOUE/NOK2PP $
COND     LGKAD1,LGKAD $  BRANCH IN NOT FREQRESP.
ALTER 114 $  SEE ALTER 113 COMMENT.
JUMP     LGKAD2 $
LABEL    LGKAD1 $
EQUIV    M2PP,M2DD/NOA/B2PP,B2DD/NOA/K2PP,K2DD/NOA/MAA,MDD/MDEMA/
         KAA,KDD/KDEKA $
LABEL    LGKAD2 $
ALTER 116,116 $
$ ADD PARAMETERS GKAD, W3 AND W4 TO GKAD.
GKAD     USETD,GM,GO,KAA,BAA,MAA,K4AA,K2PP,M2PP,B2PP/KDD,BDD,MDD,GMD,
         GOD,K2DD,M2DD,B2DD/C,Y,GKAD=TRANRESP/*DISP*/*DIRECT*/
         C,Y,G=0.0/C,Y,W3=0.0/C,Y,W4=0.0/NOK2PP/NOM2PP/
         NOB2PP/MPCF1/SINGLE/OMIT/NOUE/NOK4GG/
         NOBGG/KDEK2/-1 $
ALTER 117 $  SEE ALTER 113 COMMENT.
COND     LGKAD3,LGKAD $  BRANCH IF NOT FREQRESP.
ALTER 118 $  SEE ALTER 113 COMMENT.
JUMP     LGKAD4 $
LABEL    LGKAD3 $
EQUIV    B2DD,BDD/NOGPDT/M2DD,MDD/NOSIMP/K2DD,KDD/KDEK2 $
LABEL    LGKAD4 $
ALTER 119,123 $
$ NEW SOLUTION LOGIC
$ GENERATE TIME-DEPENDENT LOADS IF TSTEP WAS REQUESTED IN CASE CONTROL.
$ USE FOL INSTEAD OF PPF TO GET OUTPUT FREQUENCY LIST.
COND     LBLTRL1,NOTIME $
$ LOOP THRU ALL SUBCASES FOR TIME-DEPENDENT LOADS.
PARAM    //*MPY*/REPEATT /1 /-1 $
PARAM    //*ADD*/APPFLG /1 /0 $  INITIALIZE FOR SDR1.
LABEL    TRLGLOOP $
CASE     CASECC,/CASEYY/*TRAN*/S,N,REPEATT/S,N,NOLOOP1 $
PARAM    //*MPY*/NCOL /0 /1 $
TRLG     CASEYY,USETD,DLT,SLT,BGPDT,SIL,CSTM,TRL,DIT,GMD,GOD,,EST,MGG/
         ,,PDT1,PD1,,TOL/ NOSET/NCOL $
SDR1     TRL,PDT1,,,,,,,,, / ,PDT, /APPFLG/*DYNAMICS* $
SDR1     TRL,PD1 ,,,,,,,,, / ,PD , /APPFLG/*DYNAMICS* $
PARAM    //*ADD*/APPFLG /APPFLG /1 $  APPFLG=APPFLG+1.
COND     TRLGDONE,REPEATT $
REPT     TRLGLOOP,100 $
JUMP     ERROR3 $
LABEL    TRLGDONE $
FVRSTR2  TOL,,,,,,, / FRLZ,FOLZ,REORDER1,REORDER2,,,, /
         V,Y,NSEGS/V,Y,CYCIO/S,Y,LMAX=-1/FKMAX/
         S,N,FLMAX/S,N,NTSTEPS/S,N,NORO1/S,N,NORO2 $
EQUIV    FRLZ,FRL // FOLZ,FOL $
JUMP     LBLFRL2 $
LABEL    LBLTRL1 $
$ GENERATE FREQUENCY-DEPENDENT LOADS IF FREQUENCY WAS SELECTED IN CC.
FRLG     CASEXX,USETD,DLT,FRL,GMD,GOD,DIT, / PPF,PSF,PDF,FOL,PHFDUM /
         *DIRECT*/FREQY/*FREQ* $
COND     LBLFRLX1,NOFRLX $  ZERO OUT LOAD COLUMNS IF FRLX WAS GENERATED.
MPYAD    PPF,PDZERO, / PPFX /0 $
EQUIV    PPFX,PPF $
LABEL    LBLFRLX1 $
$ FORM NEW LOADS.
COND     LBLFRL1,NOBASEX $
MPYAD    M2GG,BASEXG, / M2BASEXG /0 $
ADD      PPF,M2BASEXG / PPF1 /(1.0,0.0) /(-1.0,0.0) $
EQUIV    PPF1,PPF $
COND     LBLBASE1,NOSET $
```

```
SSG2      USETD,GMD,YS,KFS,GOD,,PPF / ,PODUM1,PSF1,PDF1 $
EQUIV     PSF1,PSF // PDF1,PDF $
LABEL     LBLBASE1 $
LABEL     LBLFRL1 $
EQUIV     PPF,PDF/NOSET $
$ LOADS ARE FREQUENCY-DEPENDENT
$ PERFORM CYCLIC TRANSFORMATION ON LOADS IF CYCIO=+1.
PARAML    PDF //*TRAILER*/1 /PDFCOLS $
$ CALCULATE THE NUMBER OF LOADS FOR CYCIO=-1.
PARAM     //*DIV*/NLOAD /PDFCOLS /FKMAX $ NLOAD = NF/FKMAX
EQUIV     PDF,PXF/CYCIO $

COND      LBLPDONE,CYCIO $
$ CALCULATE THE NUMBER OF LOADS FOR CYCIO=1.
PARAM     //*DIV*/NLOAD /PDFCOLS /V,Y,NSEGS $ NLOAD = NF/NSEGS
CYCT1     PDF / PXF,GCYCF1 /CTYPE /*FORE*/V,Y,NSEGS=-1 /
          V,Y,KMAX=-1 / NLOAD /S,N,NOGO $
COND      ERRORC1,NOGO $
JUMP      LBLPDONE $
LABEL     LBLFRL2 $
$ LOADS ARE TIME-DEPENDENT
PARAM     //*NOT*/NOTCYCIO /V,Y,CYCIO $
$ BRANCH DEPENDING ON VALUE OF CYCIO
COND      LBLTRL2,NOTCYCIO $
$ CYCIO=-1
EQUIV     PD,PDTRZ1/NORO1 $
COND      LBLRO1A,NORO1 $
MPYAD     PD,REORDER1, / PDTRZ1 / 0 $
LABEL     LBLRO1A $
CYCT1     PDTRZ1 / PXTRZ1,GCYCF2 /CTYPE/*FORE*/NTSTEPS/
          V,Y,LMAX/FKMAX/S,N,NOGO $
COND      ERRORC1,NOGO $
EQUIV     PXTRZ1,PXFZ1/NORO2 $
COND      LBLRO2A,NORO2 $
MPYAD     PXTRZ1,REORDER2, / PXFZ1 /0 $
LABEL     LBLRO2A $
EQUIV     PXFZ1,PXF1 $
JUMP      LBLTRL3 $
LABEL     LBLTRL2 $
$ CYCIO = +1
MPYAD     PD,REORDER1, / PDTRZ2 / 0 $
CYCT1     PDTRZ2 /PXTRZ2,GCYCF3 /CTYPE/*FORE*/NTSTEPS/V,Y,LMAX/
               V,Y,NSEGS/S,N,NOGO $
COND      ERRORC1,NOGO $
EQUIV     PXTRZ2,PXTR2/NORO2 $
COND      LBLRO2B,NORO2 $
MPYAD     PXTRZ2,REORDER2, / PXTR2 /0 $
LABEL     LBLRO2B $
CYCT1     PXTR2 / PXFZ2,GCYCF4 / CTYPE/*FORE*/V,Y,NSEGS/V,Y,KMAX/
               FLMAX/S,N,NOGO $
COND      ERRORC1,NOGO $
EQUIV     PXFZ2,PXF1 $
LABEL     LBLTRL3 $
$ TIME-DEPENDENT LOADS ARE REAL. MAKE LOADS COMPLEX TO CORRESPOND
$ TO FREQUENCY DEPENDENT LOADS. ALSO SDR2 EXPECTS LOADS TO BE COMPLEX
$ IN FREQRESP TYPE PROBLEMS.
COPY      PXF1 / PXF2   $  CONVERT REAL PXF1 TO COMPLEX PXF.
ADD       PXF1,PXF2 / PXF / (0.5,1.0) / (0.5,-1.0) $
$ DEFINE NLOAD FOR CYCT2.
PARAM     //*ADD*/NLOAD /FLMAX /0 $  NLOAD = FLMAX
LABEL     LBLPDONE $
$
$ INITIALIZE UXVF IF KMIN IS NOT ZERO.
$
PARAM     //*ADD*/KMINL /V,Y,KINDEX=-1/-1 $
COND      NOKMINL,KMINL $
```

```
PARAM     //*ADD*/KMINV /0 /0 $
LABEL     KMINLOOP $
CYCT2     CYCDD,,,PXF,, /,,PKFZ,, / *FORE*/V,Y,NSEGS/
          KMINV/CYCSEQ/NLOAD/S,N,NOGO $
COND      ERRORC1,NOGO $
ADD       PKFZ, / UKVFZ / (0.0,0.0) $
PRTPARM   //0/*KINDEX* $
CYCT2     CYCDD,,,UKVFZ,, /,,UXVF,, /*BACK*/V,Y,NSEGS/
          KMINV/CYCSEQ/NLOAD/S,N,NOGO $
PRTPARM   //0/*KINDEX* $
COND      ERRORC1,NOGO $
PARAM     //*ADD*/KMINV /KMINV /1 $
REPT      KMINLOOP,KMINL $
LABEL     NOKMINL $
COND      NOKPRT,NOKPRT $
PRTPARM   //0/*KINDEX* $
LABEL     NOKPRT $
CYCT2     CYCDD,KDD,MDD,,, /KKKF,MKKF,,, /*FORE*/V,Y,NSEGS /
          V,Y,KINDEX/CYCSEQ/NLOAD/S,N,NOGO $
COND      ERRORC1,NOGO $
CYCT2     CYCDD,BDD,,PXF,, /BKKF,,PKF,, / *FORE*/V,Y,NSEGS/
          V,Y,KINDEX/CYCSEQ/NLOAD/S,N,NOGO $
COND      ERRORC1,NOGO $
CYCT2     CYCDD,KAA,MAA,,,/KKK,MKK,,,/*FORE*/V,Y,NSEGS/V,Y,KINDEX/
          CYCSEQ=-1/1/S,N,NOGO $
COND      ERRORC1,NOGO $
READ      KKK,MKK,,,EED,,CASECC/LAMK,PHIK,MIK,OEIGS/*MODES*/
          S,N,NEIGV $
OFP       OEIGS,,,,,//S,N,CARDNO $
COND      FINIS,NEIGV $
OFP       LAMK,,,,,//S,N,CARDNO $
COND      NOPLOT,JUMPPLOT $
CYCT2     CYCDD,,,,PHIK,LAMK/,,,PHIA,LAMA/*BACK*/V,Y,NSEGS/V,Y,KINDEX/
          CYCSEQ/1/S,N,NOGO $
COND      ERRORC1,NOGO $
SDR1      USET,,PHIA,,,GO,GM,,KFS,,/PHIG,,QG/1/*REIG* $
SDR2      CASECC,CSTM,MPT,DIT,EQEXIN,SIL,,,BGPDP,LAMA,QG,PHIG,EST,,/
          ,OQG1,OPHIG,OES1,OEF1,PPHIG/*REIG* $
PLOT      PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,,PPHIG,GPECT,/
          PLOTXX/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $
PRTMSG    PLOTXX// $
LABEL     NOPLOT $
GKAM      USETD,PHIK,MIK,LAMK,DIT,M2DD,B2DD,K2DD,CASECC/MDUM,BDUM,
          KDUM,PHIKH/NOUE/C,Y,LMODES=0/C,Y,LFREQ=0.0/C,Y,HFREQ=-1.0/
          NOM2PP/NOB2PP/NOK2PP/NONCUP/S,N,FMODE=0 $
PARAML    PHIKH//*TRAILER*/1/S,N,NMODES $
SMPYAD    PHIKH,MKKF,PHIKH,,,/MHH/3////1 $
SMPYAD    PHIKH,KKKF,PHIKH,,,/KHH/3////1 $
SMPYAD    PHIKH,BKKF,PHIKH,,,/BHH/3////1 $
MPYAD     PHIKH,PKF,/PHF/1 $
EQUIV     MHH,MKKF//BHH,BKKF//KHH,KKKF//PHF,PKF $
COND      KLABEL1,KFLAG $
$ KINDEX  IS EITHER 0 OR NSEGS/2 (NSEGS EVEN ONLY)
AFDB      EDT,USET,BGPDT,CSTM,EQEXIN,GM,GO/AERO,ACPT,,GTKA,/
          S,N,NK/S,N,NJ/V,Y,MINMACH/V,Y,MAXMACH/V,Y,IREF//
          NMODES/V,Y,KINDEX $
AMG       AERO,ACPT/AJJL,SKJ,D1JK,D2JK/NK/NJ/1 $
AMP       AJJL,SKJ,D1JK,D2JK,GTKA,PHIKH,,,USETD,AERO/QHHL,,/
          NOUE/1 $
JUMP      KLABEL2 $
LABEL     KLABEL1 $
$ KINDEX  IS .NE.0 AND .NE. NSEGS/2 (NSEGS EVEN ONLY)
CYCT2     CYCDD,,,,PHIKH,LAMK/,,,PHIAH,LAMAH/*BACK*/V,Y,NSEGS/
          V,Y,KINDEX/CYCSEQ/1/S,N,NOGO $
COND      ERRORC1,NOGO $
AFDB      EDT,USET,BGPDT,CSTM,EQEXIN,GM,GO/AERO,ACPT,,GTKA,PVECT/
```

```
         S,N,NK/S,N,NJ/V,Y,MINMACH/V,Y,MAXMACH/V,Y,IREF/*COSINE*/
         NMODES/V,Y,KINDEX $
AMG      AERO,ACPT/AJJL,SKJ,D1JK,D2JK/NK/NJ/1 $
PARTN    PHIAH,PVECT,/PHIAC,,,/1 $
AMP      AJJL,SKJ,D1JK,D2JK,GTKA,PHIAC,,,USETD,AERO/QHHLC,,/
         NOUE/1 $
APDB     EDT,USET,BGPDT,CSTM,EQEXIN,GM,GO/AERO,ACPT,,GTKA,PVECT/
         S,N,NK/S,N,NJ/V,Y,MINMACH/V,Y,MAXMACH/V,Y,IREF/*SINE*/
         NMODES/V,Y,KINDEX $
PARTN    PHIAH,PVECT,/PHIAS,,,/1 $
AMP      AJJL,SKJ,D1JK,D2JK,GTKA,PHIAS,,,USETD,AERO/QHHLS,,/
         NOUE/1 $
ADD      QHHLC,QHHLS/QHHL $
LABEL    KLABEL2 $
$ SOLUTION
FRRD2    KKKF,BKKF,MKKF,QHHL,PKF,FOL/UKVF/V,Y,BOV/V,Y,Q/-1.0 $
DDR1     UKVF,PHIKH/UKKVF $
EQUIV    UKKVF,UKVF $
CYCT2    CYCDD,,,UKVF,, /,,UXVF,, /*BACK*/V,Y,NSEGS/V,Y,KINDEX/
         CYCSEQ/NLOAD/S,N,NOGO $
COND     ERRORC1,NOGO $
EQUIV    UXVF,UDVF / CYCIO $
COND     LCYC3,CYCIO $  IF CYCIO .GE. 0 THEN TRANSFORM TO PHYSICAL.
CYCT1    UXVF / UDVF,GCYCB1 / CTYPE/*BACK*/V,Y,NSEGS/V,Y,KMAX/
         NLOAD $
LABEL    LCYC3 $
COND     LBLTRL4,NOTIME $
EQUIV    PXF,PDF2 / CYCIO $
COND     LCYC4,CYCIO $  IF CYCIO .GE. 0 THEN TRANSFORM TO PHYSICAL.
CYCT1    PXF / PDF2,GCYCB2 / CTYPE/*BACK*/V,Y,NSEGS/V,Y,KMAX/
         NLOAD $
LABEL    LCYC4 $
$ IF LOADS WERE TIME-DEPENDENT THEN RECOVER PPF AND PSF FROM PXF.
SDR1     USETD,,PDF2,,,GOD,GMD,,,, / PPFZ,, /1 /*DYNAMICS* $
SSG2     USETD,GMD,YS,KFS,GOD,,PPFZ / ,PODUM,PSFZ,PLDUM $
EQUIV    PPFZ,PPF // PSFZ,PSF $
LABEL    LBLTRL4 $
VDR      CASEXX,EQDYN,USETD,UDVF,FOL,XYCDB,/OUDVC1,/*FREQRESP*/
         *DIRECT*/S,N,NOSORT2/S,N,NOD/S,N,NOP/FMODE $
ALTER 139,139 $  USE FOL INSTEAD OF PPF TO GET OUTPUT FREQUENCY LIST.
SDR2     CASEXX,CSTM,MPT,DIT,EQDYN,SILD,,,BGPDP,FOL,QPC,UPVC,EST,XYCDB,
         PPF/OPPC1,OQPC1,OUPVC1,OESC1,OEFC1,PUPVC1/*FREQRESP*/
         S,N,NOSORT2 $
CURV     OESC1,MPT,CSTM,EST,SIL,GPL/OESC1M,/1 $
ALTER 141,142 $
SDR3     OPPC1,OQPC1,OUPVC1,OESC1,OEFC1,OESC1M/OPPC2,OQPC2,OUPVC2,
         OESC2,OEFC2,OESC2M $
OFP      OPPC2,OQPC2,OUPVC2,OEFC2,OESC2,OESC2M//S,N,CARDNO $
ALTER 153,153 $
OFP      OUPVC1,OPPC1,OQPC1,OEFC1,OESC1,OESC1M//S,N,CARDNO $
ALTER 161  $  ADD LABEL FOR ERROR3.
LABEL    ERROR3 $
ALTER 164,167 $  REMOVE ERROR1 AND ERROR2.
ALTER 169 $ FORCED VIBRATION ERRORS
LABEL    ERRORC1 $  CHECK NSEGS, KMAX AND OTHER CYCLIC DATA.
PRTPARM  //-7 /*CYCSTATICS* $
LABEL    ERRORC2 $  COUPLED MASS NOT ALLOWED.
PRTPARM  //0 /C,Y,COUPMASS $
JUMP     FINIS $
LABEL    ERRORC3 $  SUPORT BULK DATA NOT ALLOWED.
PRTPARM  //-6 /*CYCSTATICS* $
LABEL    ERRORC4 $  EPOINT BULK DATA NOT ALLOWED.
PRTPARM  //0 /*NOUE* $
JUMP     FINIS $
LABEL    ERRORC5 $  NEITHER FREQ OR TSTEP WERE IN BULK DATA DECK.
PRTPARM  //0 /*NOFRL* $
```

```
PRTPARM  //0 /*NOTRL* $
JUMP     FINIS $
LABEL    ERRORC6 $  BOTH FREQ AND TSTEP WERE SELECTED IN CASE CONTROL.
PRTPARM  //0 /*NOFREQ* $
PRTPARM  //0 /*NOTIME* $
JUMP     FINIS $
LABEL    ERRORC7 $  NO EIGENVALUE EXTRACTION DATA
PRTPARM  //-2/*CYCMODES* $
ENDALTER $
```

TABLE 3.6 DMAP Sequence of DISP APP RF 8 ALTERed by MFVAAET ALTER Package

```
 1  BEGIN     DISP 08 - DIRECT FREQUENCY/RANDOM RESPONSE ANALYSIS-APR. 1984 $
 2  PRECHK    ALL $
 3  FILE      KGGX=TAPE/KGG=TAPE/GOD=SAVE/GMD=SAVE/MDD=SAVE/BDD=SAVE $
 3  FILE      UXVF=APPEND/PDT=APPEND/PD=APPEND $
 3  COND      ERRORC1,NSEGS $  IF USER HAS NOT SPECIFIED NSEGS.
 3  COND      ERRORC1,KMAX  $  IF USER HAS NOT SPECIFIED KMAX.
 3  COND      ERRORC1,KMIN  $  IF USER HAS SPECIFIED NEGATIVE KMIN.
 3  PARAM     //*NE*/KTEST/V,Y,KMAX/V,Y,KMIN=0 $
 3  COND      LBL1KIND,KTEST $
 3  PARAM     //*ADD*/KINDEX/V,Y,KMAX/0  $  SET KINDEX = KMAX (= KMIN)
 3  JUMP      LBL2KIND $
 3  LABEL     LBL1KIND
 3  COND      ERRORC1,KINDEX  $  IF USER HAS NOT SPECIFIED KINDEX.
 3  PARAM     //*LT*/KTEST/V,Y,KINDEX/V,Y,KMIN $
 3  COND      ERRORC1,KTEST $
 3  PARAM     //*GT*/KTEST/V,Y,KINDEX/V,Y,KMAX $
 3  COND      ERRORC1,KTEST $
 3  LABEL     LBL2KIND $
 3  PARAM     //*EQ*/CYCIOERR /V,Y,CYCIO=0 /0 $
 3  COND      ERRORC1,CYCIOERR  $  IF USER HAS NOT SPECIFIED CYCIO.
 3  PARAM     //*DIV*/NSEG2 /V,Y,NSEGS /2 $  NSEG2 = NSEGS/2
 3  PARAM     //*SUB*/KMAXERR /NSEG2 /V,Y,KMAX $
 3  COND      ERRORC1,KMAXERR $  IF KMAX .GT. NSEGS/2
 3  PARAM     //*EQ*/KTEST/V,Y,KINDEX/0 $
 3  COND      LBL3KIND,KTEST $
 3  PARAM     //*ADD*/NSEGS1/V,Y,NSEGS/1 $
 3  PARAM     //*DIV*/NSEG21/NSEGS1/2 $
 3  PARAM     //*EQ*/KEVEN/NSEG21/NSEG2 $
 3  PARAM     //*EQ*/KNSEG2/NSEG2/V,Y,KINDEX $
 3  PARAM     //*EQ*/KTEST/KNSEG2/KEVEN $
 3  COND      LBL3KIND,KTEST $
 3  PARAM     //*ADD*/KTEST/1/0 $
 3  LABEL     LBL3KIND $
 3  PARAM     //*GT*/KFLAG/KTEST/0 $
 3  PARAM     //*NOP*/V,Y,NOKPRT=+1 /V,Y,LGKAD=-1 $
 3  PARAMR    //*MPY*/OMEGA /V,Y,RPS=0.0 /6.283185 $
 3  PARAMR    //*MPY*/OMEGA2 /2.0 /OMEGA $
 3  PARAMR    //*MPY*/OMEGASQR /OMEGA /OMEGA $
 3  PARAMR    //*EQ*//V,Y,RPS /0.0 ////NORPS $
 3  PARAM     //*NOT*/NOLUMP /V,Y,COUPMASS=-1 $
 3  COND      ERRORC2,NOLUMP $
 4  PARAM     //*MPY*/CARDNO/0/0 $
 5  GP1       GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/
              S,N,NOGPDT/ALWAYS=-1 $
 6  PLTTRAN   BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $
 7  PURGE     USET,GM,GO,KAA,BAA,MAA,K4AA,KFS,PSF,QPC,EST,ECT,PLTSETX,PLTPAR,
              GPSETS,ELSETS/NOGPDT $
 8  COND      LBL5,NOGPDT $
 9  GP2       GEOM2,EQEXIN/ECT $
10  PARAML    PCDB//*PRES*////JUMPPLOT $
11  PURGE     PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $
12  COND      P1,JUMPPLOT $
13  PLTSET    PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/
              S,N,JUMPPLOT $
14  PRTMSG    PLTSETX// $
15  PARAM     //*MPY*/PLTFLG/1/1 $
```

```
16   PARAM    //*MPY*/PFILE/0/0 $
17   COND     P1,JUMPPLOT $
18   PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/
              NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $
19   PRTMSG   PLOTX1//$
20   LABEL    P1 $
21   GP3      GEOM3,EQEXIN,GEOM2 / SLT,GPTT / NOGRAV $
22   TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/
              LUSET/S,N,NOSIMP/1/S,N,NOGENL/S,N,GENEL $
23   PURGE    K4GG,GPST,OGPST,MGG,BGG,K4NN,K4FF,K4AA,MNN,MFF,MAA,BNN,BFF,BAA,
              KGGX/NOSIMP/OGPST/GENEL $
23   PARAM    //*MPY*/NSKIP /0/0 $
23   GP4      CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,/RG,YS,USET,ASET/LUSET/
              S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/S,N,NSKIP/
              S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/S,Y,AUTOSPC $
23   PURGE    GM,GMD/MPCF1/GO,GOD/OMIT/KFS,PSF,QPC/SINGLE $
23   PARAM    //*NOT*/REACDATA /REACT $
23   COND     ERRORC3,REACDATA $
23   DPD      DYNAMICS,GPL,SIL,USET / GPLD,SILD,USETD,TFPOOL,DLT,PSDL,FRL,,
              TRL,EED,EQDYN / LUSET/S,N,LUSETD/NOTFL/S,N,NODLT/
              S,N,NOPSDL/S,N,NOFRL/NONLFT/S,N,NOTRL/S,N,NOEED//
              S,N,NOUE $
23   COND     ERRORC7,NOEED $
23   PARAM    //*AND*/FTERR /NOFRL /NOTRL $
23   COND     ERRORC5,FTERR $  NO FREQ OR TSTEP BULK DATA.
23   PARAML   CASECC //*DTI*/1/14//FREQSET $
23   PARAML   CASECC //*DTI*/1/38//TIMESET $
23   PARAM    //*MPY*/FREQTIME /FREQSET /TIMESET $
23   PARAM    //*NOT*/FTERR1 /FREQTIME $
23   PARAM    //*LE*/NOFREQ /FREQSET /0 $
23   PARAM    //*LE*/NOTIME /TIMESET /0 $
23   COND     ERRORC6,FTERR1 $  BOTH FREQ AND TSTEP IN CASE CONTROL DECK.
23   PARAM    //*NOT*/EXTRAPTS /NOUE $
23   COND     ERRORC4,EXTRAPTS $
23   GPCYC    GEOM4,EQDYN,USETD /CYCDD /CTYPE=ROT /S,N,NOGO $
23   COND     ERRORC1,NOGO $
24   COND     LBL1,NOSIMP $
25   PARAM    //*ADD*/NOKGGX/1/0 $
26   PARAM    //*ADD*/NOMGG/1/0 $
27   PARAM    //*ADD*/NOBGG=-1/1/0 $
28   PARAM    //*ADD*/NOK4GG/1/0 $
28   PARAM    //*NOP*/V,Y,KGGIN=-1 $
28   COND     JMPKGGIN,KGGIN $
28   PARAM    //*ADD*/NOKGGX/-1/0 $
28   INPUTT1  /KTOTAL,,,,/C,Y,LOCATION=-1/C,Y,INPTUNIT=0 $
28   EQUIV    KTOTAL,KGGX $
28   LABEL    JMPKGGIN $
29   EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,BELM,BDICT/
              S,N,NOKGGX/S,N,NOMGG/S,N,NOBGG/S,N,NOK4GG//C,Y,COUPMASS/
              C,Y,CPBAR/C,Y,CPROD/C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/
              C,Y,CPTRIA2/C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC $
30   PURGE    GPST/NOKGGX/MGG/NOMGG $
31   COND     LBLKGGX,NOKGGX $
32   EMA      GPECT,KDICT,KELM/KGGX,GPST $
33   LABEL    LBLKGGX $
33   PARAM    //*OR*/NOBM1 /NOMGG /NORPS $
33   PURGE    B1GG,M1GG /NOBM1 $
33   PURGE    M2GG,M2BASEXG /NOMGG $
34   COND     LBLMGG,NOMGG $
35   EMA      GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $
36   LABEL    LBLMGG $
36   FVRSTR1  CASECC,BGPDT,CSTM,DIT,FRL,MGG,, / FRLX,B1GG,M1GG,
              M2GG,BASEXG,PDZERO,, /NOMGG/V,Y,CYCIO/V,Y,NSEGS/
              V,Y,KMAX/S,N,FKMAX/V,Y,BXTID=-1/V,Y,BXPTID=-1/
              V,Y,BYTID=-1/V,Y,BYPTID=-1/V,Y,BZTID=-1/
              V,Y,BZPTID=-1/S,N,NOBASEX/NOFREQ/OMEGA  $
```

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36  PARAML   FRLX //*PRESENCE*////NOFRLX $
36  COND     LBLFRLX,NOFRLX $
36  EQUIV    FRLX,FRL $
36  LABEL    LBLFRLX $
37  COND     LBLBGG,NOBGG $
38  EMA      GPECT,BDICT,BELM/BGG, $
39  LABEL    LBLBGG $
40  COND     LBLK4GG,NOK4GG $
41  EMA      GPECT,KDICT,KELM/K4GG,/NOK4GG $
42  LABEL    LBLK4GG $
43  PURGE    MNN,MFF,MAA/NOMGG $
43  PARAM    //*ADD*/NOBGG /NOBM1 /0 $  RESET NOBGG.
44  PURGE    BNN,BFF,BAA/NOBGG $
45  COND     LBL1,GRDPNT $
46  COND     ERROR4,NOMGG $
47  GPWG     BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $
48  OFP      OGPWG,,,,,//S,N,CARDNO $
49  LABEL    LBL1 $
50  EQUIV    KGGX,KGG/NOGENL $
51  COND     LBL11,NOGENL $
52  SMA3     GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $
53  LABEL    LBL11 $
53  COND     LBL11A,NOBM1 $
53  PARAMR   //*COMPLEX*// OMEGA2 /0.0/ CMPLX1 $
53  PARAMR   //*SUB*/ MOMEGASQ / 0.0 / OMEGASQR $
53  PARAMR   //*COMPLEX*// MOMEGASQ / 0.0 / CMPLX2 $
53  ADD      BGG,B1GG / BGG1 / (1.0,0.0) / CMPLX1 $
53  EQUIV    BGG1,BGG $
53  ADD      KGG,M1GG / KGG1 / (1.0,0.0) / CMPLX2 $
53  EQUIV    KGG1,KGG $
53  LABEL    LBL11A
57  COND     LBL4,GENEL $
58  COND     LBL4,NOSIMP $
59  PARAM    //*EQ*/GPSPFLG/AUTOSPC/0 $
60  COND     LBL4,GPSPFLG $
61  GPSP     GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
62  OFP      OGPST,,,,,//S,N,CARDNO $
63  LABEL    LBL4 $
64  EQUIV    KGG,KNN/MPCF1/MGG,MNN/MPCF1/ BGG,BNN/MPCF1/K4GG,K4NN/MPCF1 $
65  COND     LBL2,MPCF1 $
66  MCE1     USET,RG/GM $
67  MCE2     USET,GM,KGG,MGG,BGG,K4GG/KNN,MNN,BNN,K4NN $
68  LABEL    LBL2 $
69  EQUIV    KNN,KFF/SINGLE/MNN,MFF/SINGLE/BNN,BFF/SINGLE/K4NN,K4FF/SINGLE $
70  COND     LBL3,SINGLE $
71  SCE1     USET,KNN,MNN,BNN,K4NN/KFF,KFS,,MFF,BFF,K4FF $
72  LABEL    LBL3 $
73  EQUIV    KFF,KAA/OMIT $
74  EQUIV    MFF,MAA/OMIT $
75  EQUIV    BFF,BAA/OMIT $
76  EQUIV    K4FF,K4AA/OMIT $
77  COND     LBL5,OMIT $
78  SMP1     USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
79  COND     LBLM,NOMGG $
80  SMP2     USET,GO,MFF/MAA $
81  LABEL    LBLM $
82  COND     LBLB,NOBGG $
83  SMP2     USET,GO,BFF/BAA $
84  LABEL    LBLB $
85  COND     LBL5,NOK4GG $
86  SMP2     USET,GO,K4FF/K4AA $
87  LABEL    LBL5 $
89  EQUIV    GO,GOD/NOUE/GM,GMD/NOUE $
90  PARAM    //*ADD*/NEVER/1/0 $
91  PARAM    //*MPY*/REPEATF/-1/1 $
92  BMG      MATPOOL,BGPDT,EQEXIN,CSTM/BDPOOL/S,N,NOKBFL/S,N,NOABFL/
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                 S,N,MFACT $
 93   PARAM      //*AND*/NOFL/NOABFL/NOKBFL $
 94   PURGE      KBFL/NOKBFL/ ABFL/NOABFL $
 95   COND       LBL13,NOFL $
 96   MTRXIN,    ,BDPOOL,EQDYN,,/ABFL,KBFL,/LUSETD/S,N,NOABFL/S,N,NOKBFL/
                 0 $
 97   LABEL      LBL13 $
 98   PURGE      OUDVC1,OUDVC2,XYPLTFA,OPPC1,OQPC1,OUPVC1,OESC1,OEFC1,OPPC2,
                 OQPC2,OUPVC2,OESC2,OEFC2,XYPLTF,PSDF,AUTO,XYPLTR,
                 K2PP,M2PP,B2PP,K2DD,M2DD,B2DD/NEVER $

 99   CASE       CASECC,PSDL/CASEXX/*FREQ*/S,N,REPEATF/S,N,NOLOOP $
100   MTRXIN     CASEXX,MATPOOL,EQDYN,,TFPOOL/K2DPP,M2DPP,B2PP/LUSETD/S,N,
                 NOK2DPP/S,N,NOM2DPP/S,N,NOB2PP $
101   PARAM      //*AND*/NOM2PP/NOABFL/NOM2DPP $
102   PARAM      //*AND*/NOK2PP/NOFL  /NOK2DPP $
103   EQUIV      K2DPP,K2PP/NOFL/M2DPP,M2PP/NOABFL $
104   COND       LBLFL2,NOFL $
105   ADD5       ABFL,KBFL,K2DPP,,/K2PP/(-1.0,0.0) $
106   COND       LBLFL2,NOABFL $
107   TRNSP      ABFL/ABFLT $
108   ADD        ABFLT,M2DPP/M2PP/MFACT $
109   LABEL      LBLFL2 $
110   PARAM      //*AND*/BDEBA/NOUE/NOB2PP $
111   PARAM      //*AND*/KDEK2/NOGENL/NOSIMP $
112   PARAM      //*AND*/MDEMA/NOUE/NOM2PP $
113   PURGE      K2DD/NOK2PP/M2DD/NOM2PP/B2DD/NOB2PP $
113   PARAM      //*AND*/KDEKA/NOUE/NOK2PP $
113   COND       LGKAD1,LGKAD $  BRANCH IN NOT FREQRESP.
114   EQUIV      M2PP,M2DD/NOA/B2PP,B2DD/NOA/K2PP,K2DD/NOA/
                 MAA,MDD/MDEMA/BAA,BDD/BDEBA $
114   JUMP       LGKAD2 $
114   LABEL      LGKAD1 $
114   EQUIV      M2PP,M2DD/NOA/B2PP,B2DD/NOA/K2PP,K2DD/NOA/MAA,MDD/MDEMA/
                 KAA,KDD/KDEKA $
114   LABEL      LGKAD2 $
115   COND       LBL18,NOGPDT $
116   GKAD       USETD,GM,GO,KAA,BAA,MAA,K4AA,K2PP,M2PP,B2PP/KDD,BDD,MDD,GMD,
                 GOD,K2DD,M2DD,B2DD/C,Y,GKAD=TRANRESP/*DISP*/*DIRECT*/
                 C,Y,G=0.0/C,Y,W3=0.0/C,Y,W4=0.0/NOK2PP/NOM2PP/
                 NOB2PP/MPCF1/SINGLE/OMIT/NOUE/NOK4GG/
                 NOBGG/KDEK2/-1 $
117   LABEL      LBL18 $
117   COND       LGKAD3,LGKAD $  BRANCH IF NOT FREQRESP.
118   EQUIV      B2DD,BDD/NOBGG/ M2DD,MDD/NOSIMP/ K2DD,KDD/KDEK2 $
118   JUMP       LGKAD4 $
118   LABEL      LGKAD3 $
118   EQUIV      B2DD,BDD/NOGPDT/M2DD,MDD/NOSIMP/K2DD,KDD/KDEK2 $
118   LABEL      LGKAD4 $
123   COND       LBLTRL1,NOTIME $
123   PARAM      //*MPY*/REPEATT /1 /-1 $
123   PARAM      //*ADD*/APPFLG /1 /0 $  INITIALIZE FOR SDR1.
123   LABEL      TRLGLOOP $
123   CASE       CASECC,/CASEYY/*TRAN*/S,N,REPEATT/S,N,NOLOOP1 $
123   PARAM      //*MPY*/NCOL /0 /1 $
123   TRLG       CASEYY,USETD,DLT,SLT,BGPDT,SIL,CSTM,TRL,DIT,GMD,GOD,,EST,MGG/
                 ,,PDT1,PD1,,TOL/ NOSET/NCOL $
123   SDR1       TRL,PDT1,,,,,,,,, / ,PDT, /APPFLG/*DYNAMICS* $
123   SDR1       TRL,PD1 ,,,,,,,,, / ,PD , /APPFLG/*DYNAMICS* $
123   PARAM      //*ADD*/APPFLG /APPFLG /1 $  APPFLG=APPFLG+1.
123   COND       TRLGDONE,REPEATT $
123   REPT       TRLGLOOP,100 $
123   JUMP       ERROR3 $
123   LABEL      TRLGDONE $
123   FVRSTR2    TOL,,,,,,, / FRLZ,FOLZ,REORDER1,REORDER2,,,, /
                 V,Y,NSEGS/V,Y,CYCIO/S,Y,LMAX=-1/FKMAX/
```

```
                S,N,FLMAX/S,N,NTSTEPS/S,N,NORO1/S,N,NORO2 $
123  EQUIV      FRLZ,FRL // FOLZ,FOL $
123  JUMP       LBLFRL2 $
123  LABEL      LBLTRL1 $
123  FRLG       CASEXX,USETD,DLT,FRL,GMD,GOD,DIT, / PPF,PSF,PDF,FOL,PHFDUM /
                *DIRECT*/FREQY/*FREQ* $
123  COND       LBLFRLX1,NOFRLX $  ZERO OUT LOAD COLUMNS IF FRLX WAS GENERATED.
123  MPYAD      PPF,PDZERO, / PPFX /0 $
123  EQUIV      PPFX,PPF $
123  LABEL      LBLFRLX1 $
123  COND       LBLFRL1,NOBASEX $
123  MPYAD      M2GG,BASEXG, / M2BASEXG /0 $
123  ADD        PPF,M2BASEXG / PPF1 /(1.0,0.0) /(-1.0,0.0) $
123  EQUIV      PPF1,PPF $
123  COND       LBLBASE1,NOSET $
123  SSG2       USETD,GMD,YS,KFS,GOD,,PPF / ,PODUM1,PSF1,PDF1 $
123  EQUIV      PSF1,PSF // PDF1,PDF $
123  LABEL      LBLBASE1 $
123  LABEL      LBLFRL1 $
123  EQUIV      PPF,PDF/NOSET $
123  PARAML     PDF //*TRAILER*/1 /PDFCOLS $
123  PARAM      //*DIV*/NLOAD /PDFCOLS /FKMAX $ NLOAD = NF/FKMAX
123  EQUIV      PDF,PXF/CYCIO $
123  COND       LBLPDONE,CYCIO $
123  PARAM      //*DIV*/NLOAD /PDFCOLS /V,Y,NSEGS $ NLOAD = NF/NSEGS
123  CYCT1      PDF / PXF,GCYCF1 /CTYPE /*FORE*/V,Y,NSEGS=-1 /
                V,Y,KMAX=-1 / NLOAD /S,N,NOGO $
123  COND       ERRORC1,NOGO $
123  JUMP       LBLPDONE $
123  LABEL      LBLFRL2 $
123  PARAM      //*NOT*/NOTCYCIO /V,Y,CYCIO $
123  COND       LBLTRL2,NOTCYCIO $
123  EQUIV      PD,PDTRZ1/NORO1 $
123  COND       LBLRO1A,NORO1 $
123  MPYAD      PD,REORDER1, / PDTRZ1 / 0 $
123  LABEL      LBLRO1A $
123  CYCT1      PDTRZ1 / PXTRZ1,GCYCF2 /CTYPE/*FORE*/NTSTEPS/
                V,Y,LMAX/FKMAX/S,N,NOGO $
123  COND       ERRORC1,NOGO $
123  EQUIV      PXTRZ1,PXFZ1/NORO2 $
123  COND       LBLRO2A,NORO2 $
123  MPYAD      PXTRZ1,REORDER2, / PXFZ1 /0 $
123  LABEL      LBLRO2A $
123  EQUIV      PXFZ1,PXF1 $
123  JUMP       LBLTRL3 $
123  LABEL      LBLTRL2 $
123  MPYAD      PD,REORDER1, / PDTRZ2 / 0 $
123  CYCT1      PDTRZ2 /PXTRZ2,GCYCF3 /CTYPE/*FORE*/NTSTEPS/V,Y,LMAX/
                      V,Y,NSEGS/S,N,NOGO $
123  COND       ERRORC1,NOGO $
123  EQUIV      PXTRZ2,PXTR2/NORO2 $
123  COND       LBLRO2B,NORO2 $
123  MPYAD      PXTRZ2,REORDER2, / PXTR2 /0 $
123  LABEL      LBLRO2B $
123  CYCT1      PXTR2 / PXFZ2,GCYCF4 / CTYPE/*FORE*/V,Y,NSEGS/V,Y,KMAX/
                       FLMAX/S,N,NOGO $
123  COND       ERRORC1,NOGO $
123  EQUIV      PXFZ2,PXF1 $
123  LABEL      LBLTRL3 $
123  COPY       PXF1 / PXF2  $  CONVERT REAL PXF1 TO COMPLEX PXF.
123  ADD        PXF1,PXF2 / PXF / (0.5,1.0) / (0.5,-1.0) $
123  PARAM      //*ADD*/NLOAD /FLMAX /0 $  NLOAD = FLMAX
123  LABEL      LBLPDONE $
123  PARAM      //*ADD*/KMINL /V,Y,KINDEX=-1/-1 $
123  COND       NOKMINL,KMINL $
123  PARAM      //*ADD*/KMINV /0 /0 $
```

```
123  LABEL     KMINLOOP $
123  CYCT2     CYCDD,,,PXF,, /,,PKFZ,, / *FORE*/V,Y,NSEGS/
               KMINV/CYCSEQ/NLOAD/S,N,NOGO $
123  COND      ERRORC1,NOGO $
123  ADD       PKFZ, / UKVFZ / (0.0,0.0) $
123  PRTPARM   //0/*KINDEX* $
123  CYCT2     CYCDD,,,UKVFZ,, /,,UXVF,, /*BACK*/V,Y,NSEGS/
               KMINV/CYCSEQ/NLOAD/S,N,NOGO $
123  PRTPARM   //0/*KINDEX* $
123  COND      ERRORC1,NOGO $
123  PARAM     //*ADD*/KMINV /KMINV /1 $
123  REPT      KMINLOOP,KMINL $
123  LABEL     NOKMINL $
123  COND      NOKPRT,NOKPRT $
123  PRTPARM   //0/*KINDEX* $
123  LABEL     NOKPRT $
123  CYCT2     CYCDD,KDD,MDD,,, /KKKF,MKKF,,, /*FORE*/V,Y,NSEGS /
               V,Y,KINDEX/CYCSEQ/NLOAD/S,N,NOGO $
123  COND      ERRORC1,NOGO $
123  CYCT2     CYCDD,BDD,,PXF,, /BKKF,,PKF,, / *FORE*/V,Y,NSEGS/
               V,Y,KINDEX/CYCSEQ/NLOAD/S,N,NOGO $
123  COND      ERRORC1,NOGO $
123  CYCT2     CYCDD,KAA,MAA,,,/KKK,MKK,,,/*FORE*/V,Y,NSEGS/V,Y,KINDEX/
               CYCSEQ=-1/1/S,N,NOGO $
123  COND      ERRORC1,NOGO $
123  READ      KKK,MKK,,,EED,,CASECC/LAMK,PHIK,MIK,OEIGS/*MODES*/
               S,N,NEIGV $
123  OFP       OEIGS,,,,,//S,N,CARDNO $
123  COND      FINIS,NEIGV $
123  OFP       LAMK,,,,,//S,N,CARDNO $
123  COND      NOPLOT,JUMPPLOT $
123  CYCT2     CYCDD,,,,PHIK,LAMK/,,,PHIA,LAMA/*BACK*/V,Y,NSEGS/V,Y,KINDEX/
               CYCSEQ/1/S,N,NOGO $
123  COND      ERRORC1,NOGO $
123  SDR1      USET,,PHIA,,,GO,GM,,KFS,,/PHIG,,QG/1/*REIG* $
123  SDR2      CASECC,CSTM,MPT,DIT,EQEXIN,SIL,,,BGPDP,LAMA,QG,PHIG,EST,,/
               ,OQG1,OPHIG,OES1,OEF1,PPHIG/*REIG* $
123  PLOT      PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,,PPHIG,GPECT,/
               PLOTXX/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $
123  PRTMSG    PLOTXX// $
123  LABEL     NOPLOT $
123  GKAM      USETD,PHIK,MIK,LAMK,DIT,M2DD,B2DD,K2DD,CASECC/MDUM,BDUM,
               KDUM,PHIKH/NOUE/C,Y,LMODES=0/C,Y,LFREQ=0.0/C,Y,HFREQ=-1.0/
               NOM2PP/NOB2PP/NOK2PP/NONCUP/S,N,FMODE=0 $
123  PARAML    PHIKH//*TRAILER*/1/S,N,NMODES $
123  SMPYAD    PHIKH,MKKF,PHIKH,,,/MHH/3////1 $
123  SMPYAD    PHIKH,KKKF,PHIKH,,,/KHH/3////1 $
123  SMPYAD    PHIKH,BKKF,PHIKH,,,/BHH/3////1 $
123  MPYAD     PHIKH,PKF,/PHF/1 $
123  EQUIV     MHH,MKKF//BHH,BKKF//KHH,KKKF//PHF,PKF $
123  COND      KLABEL1,KFLAG $
123  APDB      EDT,USET,BGPDT,CSTM,EQEXIN,GM,GO/AERO,ACPT,,GTKA,/
               S,N,NK/S,N,NJ/V,Y,MINMACH/V,Y,MAXMACH/V,Y,IREF//
               NMODES/V,Y,KINDEX $
123  AMG       AERO,ACPT/AJJL,SKJ,D1JK,D2JK/NK/NJ/1 $
123  AMP       AJJL,SKJ,D1JK,D2JK,GTKA,PHIKH,,,USETD,AERO/QHHL,,/
               NOUE/1 $
123  JUMP      KLABEL2 $
123  LABEL     KLABEL1 $
123  CYCT2     CYCDD,,,,PHIKH,LAMK/,,,PHIAH,LAMAH/*BACK*/V,Y,NSEGS/
               V,Y,KINDEX/CYCSEQ/1/S,N,NOGO $
123  COND      ERRORC1,NOGO $
123  APDB      EDT,USET,BGPDT,CSTM,EQEXIN,GM,GO/AERO,ACPT,,GTKA,PVECT/
               S,N,NK/S,N,NJ/V,Y,MINMACH/V,Y,MAXMACH/V,Y,IREF/*COSINE*/
               NMODES/V,Y,KINDEX $
123  AMG       AERO,ACPT/AJJL,SKJ,D1JK,D2JK/NK/NJ/1 $
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123  PARTN    PHIAH,PVECT,/PHIAC,,,/1 $
123  AMP      AJJL,SKJ,D1JK,D2JK,GTKA,PHIAC,,,USETD,AERO/QHHLC,,/
              NOUE/1 $
123  APDB     EDT,USET,BGPDT,CSTM,EQEXIN,GM,GO/AERO,ACPT,,GTKA,PVECT/
              S,N,NK/S,N,NJ/V,Y,MINMACH/V,Y,MAXMACH/V,Y,IREF/*SINE*/
              NMODES/V,Y,KINDEX $
123  PARTN    PHIAH,PVECT,/PHIAS,,,/1 $
123  AMP      AJJL,SKJ,D1JK,D2JK,GTKA,PHIAS,,,USETD,AERO/QHHLS,,/
              NOUE/1 $
123  ADD      QHHLC,QHHLS/QHHL $
123  LABEL    KLABEL2 $
123  FRRD2    KKKF,BKKF,MKKF,QHHL,PKF,FOL/UKVF/V,Y,BOV/V,Y,Q/-1.0 $
123  DDR1     UKVF,PHIKH/UKKVF $

123  EQUIV    UKKVF,UKVF $
123  CYCT2    CYCDD,,,UKVF,, /,,UXVF,, /*BACK*/V,Y,NSEGS/V,Y,KINDEX/
              CYCSEQ/NLOAD/S,N,NOGO $
123  COND     ERRORC1,NOGO $
123  EQUIV    UXVF,UDVF / CYCIO $
123  COND     LCYC3,CYCIO $  IF CYCIO .GE. O THEN TRANSFORM TO PHYSICAL.
123  CYCT1    UXVF / UDVF,GCYCB1 / CTYPE/*BACK*/V,Y,NSEGS/V,Y,KMAX/
              NLOAD $
123  LABEL    LCYC3 $
123  COND     LBLTRL4,NOTIME $
123  EQUIV    PXF,PDF2 / CYCIO $
123  COND     LCYC4,CYCIO $  IF CYCIO .GE. O THEN TRANSFORM TO PHYSICAL.
123  CYCT1    PXF / PDF2,GCYCB2 / CTYPE/*BACK*/V,Y,NSEGS/V,Y,KMAX/
              NLOAD $
123  LABEL    LCYC4 $
123  SDR1     USETD,,PDF2,,,GOD,GMD,,,, / PPFZ,, /1 /*DYNAMICS* $
123  SSG2     USETD,GMD,YS,KFS,GOD,,PPFZ / ,PODUM,PSFZ,PLDUM $
123  EQUIV    PPFZ,PPF // PSFZ,PSF $
123  LABEL    LBLTRL4 $
123  VDR      CASEXX,EQDYN,USETD,UDVF,FOL,XYCDB,/OUDVC1,/*FREQRESP*/
              *DIRECT*/S,N,NOSORT2/S,N,NOD/S,N,NOP/FMODE $
124  COND     LBL15,NOD $
125  COND     LBL15A,NOSORT2 $
126  SDR3     OUDVC1,,,,,/OUDVC2,,,,, $
127  OFP      OUDVC2,,,,,//S,N,CARDNO $
128  XYTRAN   XYCDB,OUDVC2,,,,/XYPLTFA/*FREQ*/*DSET*/S,N,PFILE/
              S,N,CARDNO $
129  XYPLOT   XYPLTFA// $
130  JUMP     LBL15 $
131  LABEL    LBL15A $
132  OFP      OUDVC1,,,,,//S,N,CARDNO $
133  LABEL    LBL15 $
134  COND     LBL20,NOP $
135  EQUIV    UDVF,UPVC/NOA $
136  COND     LBL19,NOA $
137  SDR1     USETD,,UDVF,,,GOD,GMD,PSF,KFS,,/UPVC,,QPC/1/*DYNAMICS* $
138  LABEL    LBL19 $
139  SDR2     CASEXX,CSTM,MPT,DIT,EQDYN,SILD,,,BGPDP,FOL,QPC,UPVC,EST,XYCDB,
              PPF/OPPC1,OQPC1,OUPVC1,OESC1,OEFC1,PUPVC1/*FREQRESP*/
              S,N,NOSORT2 $
139  CURV     OESC1,MPT,CSTM,EST,SIL,GPL/OESC1M,/1 $
140  COND     LBL17,NOSORT2 $
142  SDR3     OPPC1,OQPC1,OUPVC1,OESC1,OEFC1,OESC1M/OPPC2,OQPC2,OUPVC2,
              OESC2,OEFC2,OESC2M $
142  OFP      OPPC2,OQPC2,OUPVC2,OEFC2,OESC2,OESC2M//S,N,CARDNO $
143  XYTRAN   XYCDB,OPPC2,OQPC2,OUPVC2,OESC2,OEFC2/XYPLTF/*FREQ*/*PSET*/
              S,N,PFILE/S,N,CARDNO $
144  XYPLOT   XYPLTF// $
145  COND     LBL16,NOPSDL $
146  RANDOM   XYCDB,DIT,PSDL,OUPVC2,OPPC2,OQPC2,OESC2,OEFC2,CASEXX/PSDF,AUTO/
              S,N,NORD $
147  COND     LBL16,NORD $
```

```
148   XYTRAN     XYCDB,PSDF,AUTO,,,/XYPLTR/*RAND*/*PSET*/S,N,PFILE/
                 S,N,CARDNO $
149   XYPLOT     XYPLTR// $
150   JUMP       LBL16 $
151   LABEL      LBL17 $
152   PURGE      PSDF/NOSORT2 $
153   OFP        OUPVC1,OPPC1,OQPC1,OEFC1,OESC1,OESC1M//S,N,CARDNO $
154   LABEL      LBL16 $
155   PURGE      PSDF/NOPSDL $
156   COND       LBL20,JUMPPLOT $
157   PLOT       PLTPAR,GPSETS,ELSETS,CASEXX,BGPDT,EQEXIN,SIP,,PUPVC1,
                 GPECT,OESC1/PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/
                 S,N,PFILE $
158   PRTMSG     PLOTX2// $
159   LABEL      LBL20 $
160   COND       FINIS,REPEATF $
161   REPT       LBL13,100 $
161   LABEL      ERROR3 $
162   PRTPARM    //-3/*DIRFRRD* $
163   JUMP       FINIS $
168   LABEL      ERROR4 $
169   PRTPARM    //-4/*DIRFRRD* $
169   LABEL      ERRORC1 $  CHECK NSEGS, KMAX AND OTHER CYCLIC DATA.
169   PRTPARM    //-7 /*CYCSTATICS* $
169   LABEL      ERRORC2 $  COUPLED MASS NOT ALLOWED.
169   PRTPARM    //0 /C,Y,COUPMASS $
169   JUMP       FINIS $
169   LABEL      ERRORC3 $  SUPORT BULK DATA NOT ALLOWED.
169   PRTPARM    //-6 /*CYCSTATICS* $
169   LABEL      ERRORC4 $  EPOINT BULK DATA NOT ALLOWED.
169   PRTPARM    //0 /*NOUE* $
169   JUMP       FINIS $
169   LABEL      ERRORC5 $  NEITHER FREQ OR TSTEP WERE IN BULK DATA DECK.
169   PRTPARM    //0 /*NOFRL* $
169   PRTPARM    //0 /*NOTRL* $
169   JUMP       FINIS $
169   LABEL      ERRORC6 $  BOTH FREQ AND TSTEP WERE SELECTED IN CASE CONTROL.
169   PRTPARM    //0 /*NOFREQ* $
169   PRTPARM    //0 /*NOTIME* $
169   JUMP       FINIS $
169   LABEL      ERRORC7 $  NO EIGENVALUE EXTRACTION DATA
169   PRTPARM    //-2/*CYCMODES* $
170   LABEL      FINIS $
171   PURGE      DUMMY/ALWAYS $
172   END        $
```

SECTION 4

SUPPLEMENT TO
NASTRAN DEMONSTRATION MANUAL

MODAL FORCED VIBRATION ANALYSIS OF AERODYNAMICALLY EXCITED TURBOSYSTEMS

4.1 INTRODUCTION

The principal purpose of this section is to demonstrate the use of the newly developed capability in NASTRAN to conduct modal forced vibration analysis of rotating turbosystems subjected to excitation from aerodynamic sources. The demonstration comprises a series of four inter-related analysis phases:

Phase 1 generates a total stiffness matrix consisting of elastic plus differential stiffness matrices.

Phase 2 ascertains the aeroelastic stability of the turbosystem before proceeding with response analysis.

Phase 3 generates the applied oscillatory airloads on the blades of the turbosystem.

Phase 4 determines the aerodynamically forced response of the turbosystem.

4.2 EXAMPLE PROBLEM DESCRIPTION

An eight-bladed single-rotation advanced turboprop (Figure 4.1) is selected as an example of turbosystems.

The swept blades of the turboprop are set at an angle of 60.8° with the plane of rotation, when measured at 3/4 tip radius. The prop rotates at a constant 8000 rpm. Its axis of rotation is

inclined at 2° with the uniform absolute inflow. The freestream inflow conditions are given by 0.798 Mach number, 873 fps inflow velocity, and 1.9034×10^{-3} lbf-sec^2/ft^4 inflow density.

This operating condition results in oscillatory airloads acting on the blades of the turboprop at an excitation frequency of one-per-rev (corresponding to 133.34 Hz.).

It is desired to obtain the resultant blade surface vibratory stress distribution for comparison with experimental observations.

4.3 INPUT

Figure 4.2 illustrates the NASTRAN model of one representative blade of the turboprop. For present, the hub is considered rigid, and the blade is completely fixed at the bottom of its shank.

The input data decks for all four phases discussed above are included in this section.

Phases 1, 2, and 4 use NASTRAN, while Phase 3 uses AIRLOADS program (Ref. 2).

4.4 RESULTS

Figure 4.3 compares the analytical and test stresses.

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OF POOR QUALITY

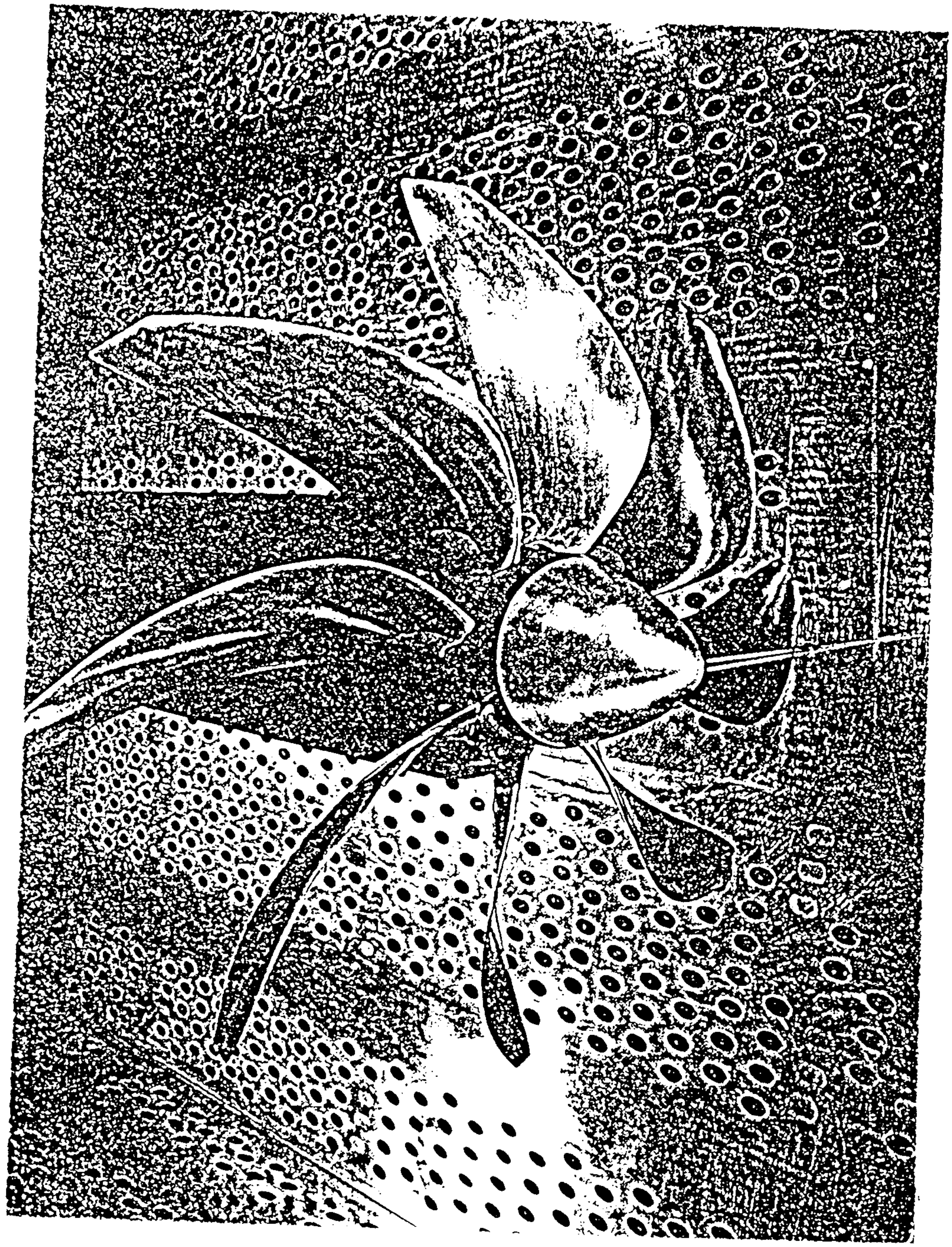

Figure 4.1 An Eight-Bladed Single-Rotation Advanced Turboprop

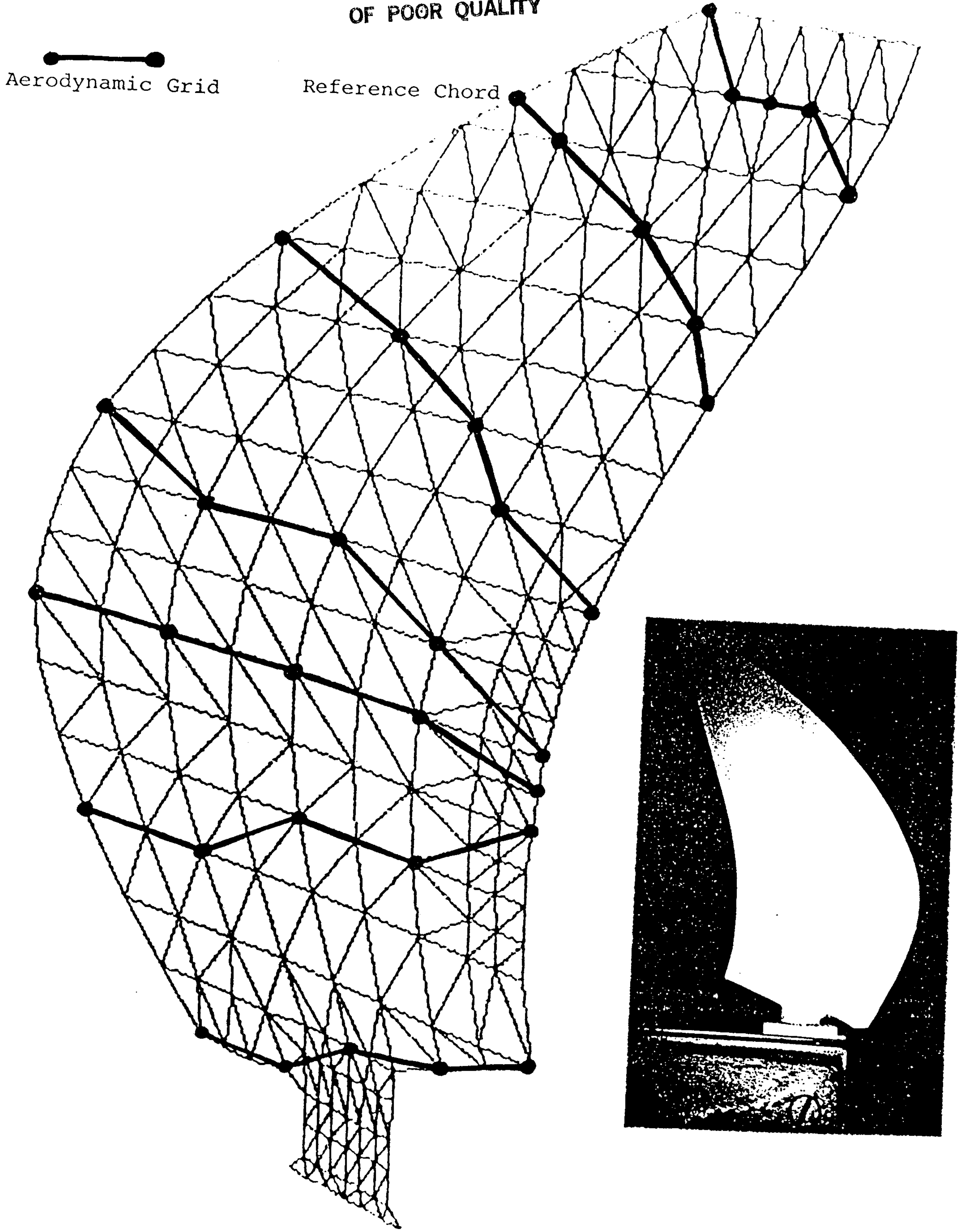

Figure 4.2 NASTRAN Structural and Aerodynamic Models of SR-3

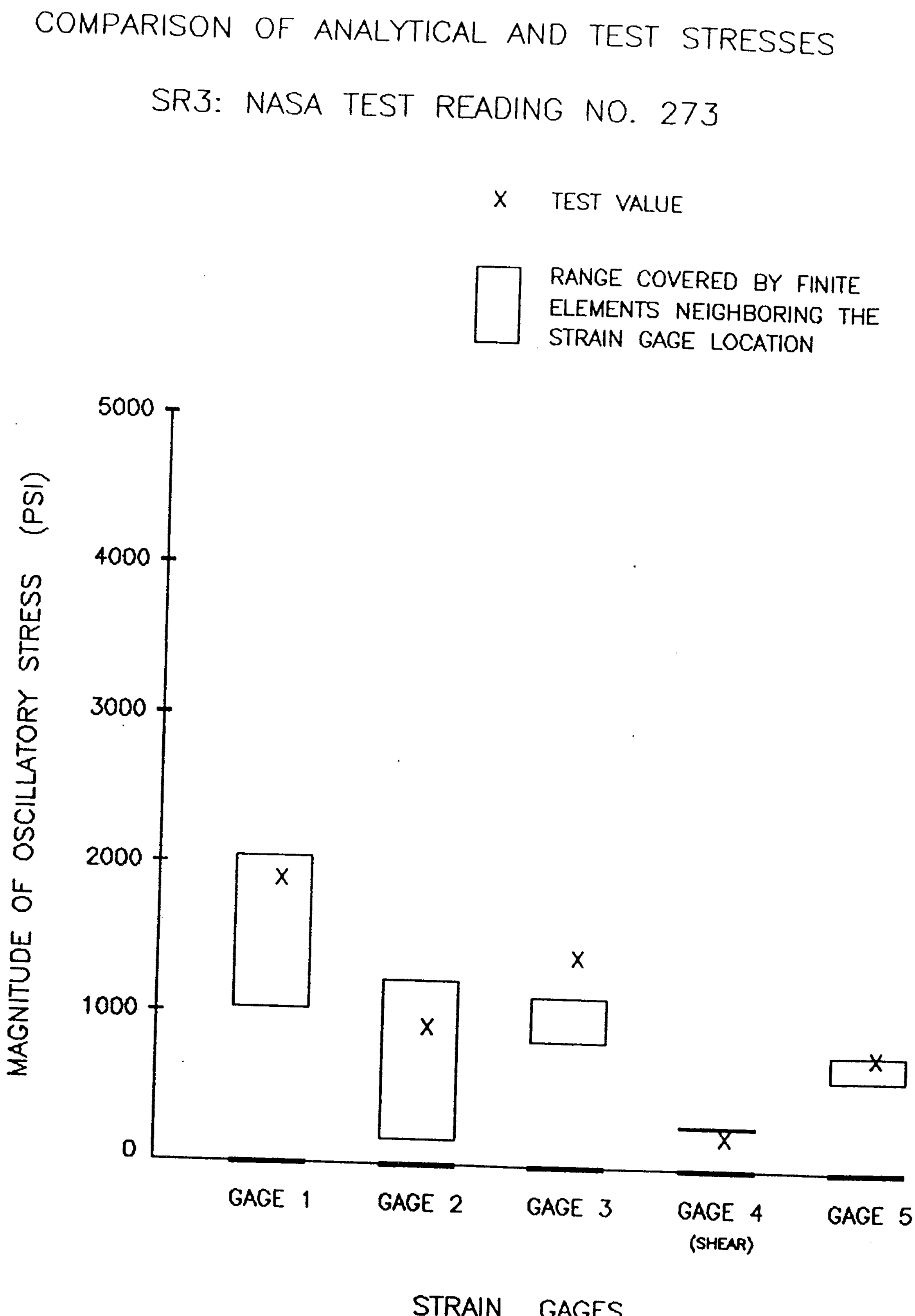

Figure 4.3 SR-3 One-Per-Rev Stress Comparison--Test Reading No. 273

INPUT DATA DECK FOR DIFFERENTIAL STIFFNESS ANALYSIS

```
NASTRAN BANDIT = -1, FILES = (INPT, PLT2)
```

EXECUTIVE CONTROL DECK

```
ID          NASA,SR3PROP
APP         DISP
SOL         4
DIAG        8,14,21,22
TIME        10   $ CRAY-1 S
$
$      ALTERS TO SAVE ELASTIC PLUS DIFFERENTIAL STIFFNESS   (KTOTAL)
$                      (APRIL 1984 VERSION)
$
ALTER 149 $
ADD        DKDGG,KDGG / KDGGX / (-1.0,0.0) $
ADD        KGG,KDGGX  / KTOTAL $
OUTPUT1 KTOTAL,,,,//-1/0 $
OUTPUT1, ,,,,//-3/0 $
ENDALTER $
$
CEND
```

CASE CONTROL DECK

```
$
TITLE = SR3 RESPONSE TO 1 PER REV OSC. AIRLOADS
SUBTITLE = NASA TEST READING NO. 273
LABEL = DIFFERENTIAL STIFFNESS ANALYSIS
$
  SPC     = 1
  MPC     = 1
  LOAD    = 1
$
  SUBCASE 1
    LABEL = DIFF. STIFF. ANAL.--LINEAR SOLUTION
    DISP  = ALL
    STRESS = ALL
  SUBCASE 2
    LABEL = DIFF. STIFF. ANAL.--NONLINEAR SOLUTION
    DISP(SORT1,PRINT) = ALL
    STRESS = ALL
$
OUTPUT (PLOT)
  SET 1 = ALL
    PLOTTER NASTPLT, MODEL D, 0
    PAPER SIZE  8.0 BY 8.0
    MAXIMUM DEFORMATION 1.0
    FIND SCALE, ORIGIN 1, SET 1
    PTITLE = SOL 4
    CONTOUR YDISPLAC
    PLOT STATIC DEFORMATION CONTOUR 0, 1,SET 1, ORIGIN 1, OUTLINE
    CONTOUR YDISPLAC
    PLOT STATIC DEFORMATION CONTOUR 0, 2,SET 1, ORIGIN 1, OUTLINE
BEGIN BULK
```

```
RFORCE  1       0       0       133.33  1.0     0.0     0.0
MAT1            1 1.6   E7              .35     .0004141
CTRIA2          1       1       10      9       8
PTRIA2          1       1 0.01570
CTRIA2          2       2       11      10      8
PTRIA2          2       1 0.02827
CTRIA2          4       4       12      11      7
PTRIA2          4       1 0.03380
CTRIA2          6       6       13      12      1
PTRIA2          6       1 0.03623
CTRIA2          7       7       1       2       13
PTRIA2          7       1 0.02917
CTRIA2          8       8       14      13      2
PTRIA2          8       1 0.04440
CTRIA2          9       9       2       3       14
PTRIA2          9       1 0.03830
CTRIA2          10      10      15      14      3
PTRIA2          10      1 0.04253
CTRIA2          11      11      3       4       15
PTRIA2          11      1 0.03677
CTRIA2          12      12      16      15      4
PTRIA2          12      1 0.03397
CTRIA2          13      13      4       5       16
PTRIA2          13      1 0.02740
CTRIA2          14      14      17      16      5
PTRIA2          14      1 0.01673
CTRIA2          15      15      5       6       17
PTRIA2          15      1 0.00823
CTRIA2          16      16      20      19      18
PTRIA2          16      1 0.01970
CTRIA2          17      17      21      20      18
PTRIA2          17      1 0.03550
CTRIA2          19      19      22      21      9
PTRIA2          19      1 0.04250
CTRIA2          20      20      9       10      22
PTRIA2          20      1 0.03487
CTRIA2          21      21      10      11      22
PTRIA2          21      1 0.04743
CTRIA2          22      22      23      22      11
PTRIA2          22      1 0.05847
CTRIA2          23      23      11      12      23
PTRIA2          23      1 0.05413
CTRIA2          24      24      24      23      12
PTRIA2          24      1 0.06033
CTRIA2          25      25      12      13      24
PTRIA2          25      1 0.05580
CTRIA2          26      26      25      24      13
PTRIA2          26      1 0.05663
CTRIA2          27      27      13      14      25
PTRIA2          27      1 0.05230
CTRIA2          28      28      14      15      25
PTRIA2          28      1 0.04877
```

⋮

CTRIA2 AND PTRIA2 DATA IDENTICAL TO THAT FOR FORCED RESPONSE ANALYSIS

⋮

C-2

```
CTRIA2      340     340     194     195     202
PTRIA2      340       1 1.06600
CTRIA2      341     341     195     196     202
PTRIA2      341       1 1.06600
CTRIA2      342     342     203     202     196
PTRIA2      342       1 1.13913
CTRIA2      343     343     196     197     203
PTRIA2      343       1 1.06487
CTRIA2      344     344     204     203     197
PTRIA2      344       1 1.06620
CTRIA2      345     345     197     198     204
PTRIA2      345       1 0.70640
CTRIA2      346     346     205     204     198
PTRIA2      346       1 0.55867
CTRIA2        3       3       8       7      11
PTRIA2        3       1 0.01897
CTRIA2        5       5       7       1      12
PTRIA2        5       1 0.02043
CTRIA2       18      18      18       9      21
PTRIA2       18       1 0.02390
CTRIA2      143     143      79      83      92
PTRIA2      143       1 0.13113
CTRIA2      166     166      92      96     105
PTRIA2      166       1 0.14623
CTRIA2      189     189     105     109     118
PTRIA2      189       1 0.15213
CTRIA2      212     212     118     122     131
PTRIA2      212       1 0.15470
CTRIA2      235     235     131     135     144
PTRIA2      235       1 0.15577
CTRIA2      275     275     166     165     153
PTRIA2      275       1 0.51933
CTRIA2      277     277     167     166     154
PTRIA2      277       1 0.31070
CTRIA2      285     285     176     177     160
PTRIA2      285       1 0.67620
CTRIA2      287     287     168     177     160
PTRIA2      287       1 0.72723
CTRIA2      288     288     168     178     177
PTRIA2      288       1 0.65833
CORD2R  77      0       .0      .0      .0      .0      .0      1.      +C2R
+C2R    10.     -0.618  .0
GRDSET          77
GRID        1           1.808   1.839  12.250
GRID        3           2.376   2.347  12.250
GRID        4           2.625   2.558  12.250
GRID        5           2.877   2.765  12.250
GRID        6           3.134   2.966  12.250
GRID        7           1.556   1.589  12.033
GRID        8           1.304   1.339  11.817
GRID        9           1.052   1.088  11.600
GRID       10           1.293   1.308  11.600
GRID       12           1.791   1.730  11.600
```

⋮

GRID DATA IDENTICAL TO THAT FOR FORCED RESPONSE ANALYSIS

⋮

GRID		170		-0.183	-0.030	2.930			
GRID		171		0.000	0.000	2.930			
GRID		172		0.183	0.030	2.930			
GRID		173		0.365	0.059	2.930			
GRID		174		0.548	0.089	2.930			
GRID		175		-1.804	-0.270	2.650			
GRID		176		-1.188	-0.182	2.650			
GRID		177		-0.750	-0.123	2.740			
GRID		178		-0.550	-0.072	2.600			
GRID		179		-0.367	-0.048	2.600			
GRID		180		-0.184	-0.024	2.600			
GRID		181		0.000	0.000	2.600			
GRID		182		0.184	0.024	2.600			
GRID		183		0.367	0.048	2.600			
GRID		184		0.550	0.072	2.600			
GRID		185		-0.550	-0.072	2.350			
GRID		186		-0.367	-0.048	2.350			
GRID		187		-0.184	-0.024	2.350			
GRID		188		0.000	0.000	2.350			
GRID		189		0.184	0.024	2.350			
GRID		190		0.367	0.048	2.350			
GRID		191		0.550	0.072	2.350			
GRID		192		-0.550	-0.072	2.070			
GRID		193		-0.367	-0.048	2.070			
GRID		194		-0.184	-0.024	2.070			
GRID		195		0.000	0.000	2.070			
GRID		196		0.184	0.024	2.070			
GRID		197		0.367	0.048	2.070			
GRID		198		0.550	0.072	2.070			
GRID		199		-0.699	-0.091	1.920			
GRID		200		-0.466	-0.061	1.920			
GRID		201		-0.233	-0.030	1.920			
GRID		202		0.000	0.000	1.920			
GRID		203		0.233	0.030	1.920			
GRID		204		0.466	0.061	1.920			
GRID		205		0.699	0.091	1.920			
GRID		206		-1.496	-0.226	2.650			
GRID		2		2.129	2.133	12.250			
GRID		11		1.541	1.520	11.600			
GRID		21		1.034	1.014	11.000			
GRID		30		0.550	0.564	10.400			
GRID		39		0.101	0.182	9.800			
GRID		48		-0.317	-0.138	9.187			
GRID		57		-0.677	-0.383	8.600			
GRID		66		-0.998	-0.572	8.000			
GRID		75		-1.271	-0.702	7.400			
GRID		88		-1.490	-0.779	6.800			
GRID		101		-1.621	-0.796	6.200			
GRID		114		-1.642	-0.753	5.600			
GRID		127		-1.572	-0.662	5.000			
GRID		140		-1.435	-0.538	4.400			
GRID		150		-1.208	-0.374	3.715			
GRID		160		-0.917	-0.229	3.180			
MPC	1	6	4	1.0	4	4	-1.0		
MPC	1	5	4	1.0	4	4	-1.0		
MPC	1	7	4	1.0	1	4	-1.0		
SEQGP		1	9	2	8	3	7	4	4
SEQGP		5	2	6	1	7	10	8	11
SEQGP		9	20	10	19	11	18	12	17
SEQGP		13	16	14	15	15	12	16	5
SEQGP		17	3	18	21	19	30	20	29
SEQGP		21	28	22	27	23	26	24	25
SEQGP		25	22	26	13	27	6	28	39
SEQGP		29	38	30	37	31	36	32	35
SEQGP		33	34	34	31	35	23	36	14
SEQGP		37	47	38	48	39	46	40	45

```
SEQGP           41      44      42      43      43      40      44      32
SEQGP           45      24      46      56      47      57      48      55
SEQGP           49      54      50      53      51      52      52      49
SEQGP           53      41      54      33      55      66      56      67
SEQGP           57      65      58      64      59      63      60      62
SEQGP           61      58      62      50      63      42      64      76
SEQGP           65      77      66      75      67      74      68      73
SEQGP           69      72      70      68      71      59      72      51
SEQGP           73      86      74      87      75      85      76      84
SEQGP           77      83      78      82      79      78      80      69
SEQGP           81      61      82      60      83      79      84      71
SEQGP           85      70      86      88      87      99      88      98
SEQGP           89      97      90      96      91      95      92      91
SEQGP           93      92      94      81      95      80      96      103
SEQGP           97      94      98      93      99      89      100     100
SEQGP           101     110     102     109     103     108     104     107
SEQGP           105     104     106     114     107     106     108     105
SEQGP           109     115     110     118     111     117     112     90
SEQGP           113     101     114     111     115     121     116     120
SEQGP           117     119     118     116     119     127     120     128
SEQGP           121     132     122     130     123     139     124     145
SEQGP           125     102     126     112     127     122     128     134
SEQGP           129     133     130     129     131     131     132     142
SEQGP           133     150     134     157     135     144     136     156
SEQGP           137     169     138     113     139     123     140     135
SEQGP           141     146     142     140     143     141     144     143
SEQGP           145     154     146     167     147     179     148     124
SEQGP           149     136     150     147     151     151     152     152
SEQGP           153     153     154     155     155     166     156     178
SEQGP           157     125     158     137     159     148     160     158
SEQGP           161     160     162     161     163     162     164     163
SEQGP           165     165     166     164     167     168     168     170
SEQGP           169     172     170     173     171     174     172     175
SEQGP           173     176     174     177     175     126     176     149
SEQGP           177     159     178     171     179     180     180     182
SEQGP           181     183     182     184     183     185     184     186
SEQGP           185     181     186     187     187     190     188     191
SEQGP           189     192     190     193     191     194     192     188
SEQGP           193     195     194     197     195     198     196     199
SEQGP           197     200     198     201     199     189     200     196
SEQGP           201     202     202     203     203     204     204     205
SEQGP           205     206     206     138
SPC1    1       5       17      27      36      14      10      45
SPC1    1       5       23      54      37      112     146     185
SPC1    1       5       186     192     187     188     189     190
SPC1    1       5       191     193     194     195     196     197
SPC1    1       5       198
SPC1    1       123456  199     THRU    205
ENDDATA
```

INPUT DATA DECK FOR
AEROELASTIC STABILITY ANALYSIS

```
NASTRAN BANDIT = -1, SYSTEM(93)=1, FILES = (INPT, PLT2)
```

EXECUTIVE CONTROL DECK

```
ID          NASA,SR3PROP
APP         AERO
SOL         9
DIAG        8,14,21,22
TIME        10   $ CRAY-1 S
$
$  ALTERS TO ADD - OMEGA**2 M TERMS TO TOTAL STIFFNESS
$
ALTER 26
PARAMR     //*MPY*/ OMEGA /V,Y,RPS=0.0/ 6.283185 $
PARAMR     //*MPY*/ OMEGASQR / OMEGA /OMEGA $
PARAMR     //*SUB*/ MOMEGASQ /0.0 /OMEGASQR $
PARAMR     //*COMPLEX*// MOMEGASQ /0.0/ CMPLX2 $
$
FVRSTR1    CASECC,BGPDT,CSTM,DIT,,MGG,,/,DUMDUM,M1GG,,,,,/NOMGG/V,Y,CYCIO/
           V,Y,NSEGS/0/S,N,FKMAX/-1/-1/-1/-1/-1/-1/S,N,NOBASEX/1/OMEGA $
$
ADD        KGGX,M1GG / KGG1 / (1.0,0.0) / CMPLX2 $
EQUIV      KGG1,KGGX $
ENDALTER
$
CEND
```

CASE CONTROL DECK

```
$
TITLE = SR3 RESPONSE TO 1 PER REV OSC. AIRLOADS
SUBTITLE = NASA TEST READING NO. 273
LABEL = AEROELASTIC STABILITY ANALYSIS
$
  SPC     = 1
  MPC     = 1
  METHOD = 1
  FMETHOD = 1
$
OUTPUT (XYOUT)
    PLOTTER NASTPLT, MODEL D, 0
    XPAPER = 8.0
    YPAPER = 11.0
    YAXIS  = YES
    XINTERCEPT = 9163.9  $ OPERATING (MEAN RELATIVE) VELOCITY
    XTAXIS = YES
    XBAXIS = YES
    CURVELINESYMBOL = 5
    XDIVISIONS = 10
    YTDIVISIONS = 10
    YBDIVISIONS = 10
    YTGRID LINES = YES
    YBGRID LINES = YES
    XTGRID LINES = YES
    XBGRID LINES = YES
    XTITLE =                    VELOCITY  VSBAR  IN/SEC
    YTTITLE =              DAMPING  G
    YBTITLE =         FREQUENCY F, HZ
    TCURVE =     K = .179       SIGMA = -45.0 DEG.
    XYPLOT,XYPRINT VG/ 1(G,F),2(G,F),3(G,F),4(G,F),5(G,F)
BEGIN BULK
```

CORD2R	77	0	.0	.0	.0	.0	.0	1.	+C2R
+C2R	10.	-0.618	.0						
CTRIA2	1	1	10	9	8				
CTRIA2	2	2	11	10	8				
CTRIA2	3	3	8	7	11				
CTRIA2	4	4	12	11	7				
CTRIA2	5	5	7	1	12				
CTRIA2	6	6	13	12	1				
CTRIA2	7	7	1	2	13				
CTRIA2	8	8	14	13	2				
CTRIA2	9	9	2	3	14				
CTRIA2	10	10	15	14	3				
CTRIA2	11	11	3	4	15				
CTRIA2	12	12	16	15	4				
CTRIA2	13	13	4	5	16				
CTRIA2	14	14	17	16	5				
CTRIA2	15	15	5	6	17				
CTRIA2	16	16	20	19	18				
CTRIA2	17	17	21	20	18				
CTRIA2	18	18	18	9	21				
CTRIA2	19	19	22	21	9				
CTRIA2	20	20	9	10	22				
CTRIA2	21	21	10	11	22				
CTRIA2	22	22	23	22	11				
CTRIA2	23	23	11	12	23				
CTRIA2	24	24	24	23	12				
CTRIA2	25	25	12	13	24				
CTRIA2	26	26	25	24	13				
CTRIA2	27	27	13	14	25				
CTRIA2	28	28	14	15	25				
CTRIA2	29	29	26	25	15				
CTRIA2	30	30	15	16	26				
CTRIA2	31	31	27	26	16				
CTRIA2	32	32	16	17	27				
CTRIA2	33	33	29	28	19				
CTRIA2	34	34	30	29	19				
CTRIA2	35	35	19	20	30				
CTRIA2	36	36	31	30	20				
CTRIA2	37	37	20	21	31				
CTRIA2	38	38	32	31	21				
CTRIA2	39	39	21	22	32				
CTRIA2	40	40	33	32	22				
CTRIA2	41	41	22	23	33				
CTRIA2	42	42	23	24	33				
CTRIA2	43	43	34	33	24				
CTRIA2	44	44	24	25	34				
CTRIA2	45	45	35	34	25				
CTRIA2	46	46	25	26	35				
CTRIA2	47	47	36	35	26				
CTRIA2	48	48	26	27	36				
CTRIA2	49	49	38	37	28				
CTRIA2	50	50	28	29	39				
CTRIA2	51	51	39	38	28				

⋮

CTRIA2 DATA IDENTICAL TO THAT FOR FORCED RESPONSE ANALYSIS

⋮

```
CTRIA2  326     326     194     193     187
CTRIA2  327     327     187     188     194
CTRIA2  328     328     195     194     188
CTRIA2  329     329     188     189     195
CTRIA2  330     330     196     195     189
CTRIA2  331     331     189     190     196
CTRIA2  332     332     197     196     190
CTRIA2  333     333     190     191     197
CTRIA2  334     334     198     197     191
CTRIA2  335     335     200     199     192
CTRIA2  336     336     192     193     200
CTRIA2  337     337     201     200     193
CTRIA2  338     338     193     194     201
CTRIA2  339     339     202     201     194
CTRIA2  340     340     194     195     202
CTRIA2  341     341     195     196     202
CTRIA2  342     342     203     202     196
CTRIA2  343     343     196     197     203
CTRIA2  344     344     204     203     197
CTRIA2  345     345     197     198     204
CTRIA2  346     346     205     204     198
CYJOIN  1               199
CYJOIN  2               205
EIGR    1       FEER                            4                               +EIG1
+EIG1   MAX
GRDSET          77
GRID            1            1.808    1.839   12.250
GRID            3            2.376    2.347   12.250
GRID            4            2.625    2.558   12.250
GRID            5            2.877    2.765   12.250
GRID            6            3.134    2.966   12.250
GRID            7            1.556    1.589   12.033
GRID            8            1.304    1.339   11.817
GRID            9            1.052    1.088   11.600
GRID            10           1.293    1.308   11.600
GRID            12           1.791    1.730   11.600
GRID            13           2.044    1.937   11.600
GRID            14           2.298    2.141   11.600
GRID            15           2.555    2.343   11.600
GRID            16           2.814    2.542   11.600
GRID            17           3.078    2.733   11.600
GRID            18           0.737    0.793   11.300
GRID            19           0.423    0.498   11.000
GRID            20           0.725    0.761   11.000
GRID            22           1.347    1.264   11.000
GRID            23           1.663    1.510   11.000
GRID            24           1.981    1.753   11.000
GRID            25           2.302    1.993   11.000
GRID            26           2.626    2.228   11.000
GRID            27           2.956    2.454   11.000
GRID            28          -0.168   -0.013   10.400
GRID            29           0.186    0.281   10.400
GRID            31           0.917    0.842   10.400
GRID            32           1.288    1.115   10.400
```

⋮

GRID DATA IDENTICAL TO THAT FOR FORCED RESPONSE ANALYSIS

⋮

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OF POOR QUALITY

```
GRID          188          0.000    0.000    2.350
GRID          189          0.184    0.024    2.350
GRID          190          0.367    0.048    2.350
GRID          191          0.550    0.072    2.350
GRID          192         -0.550   -0.072    2.070
GRID          193         -0.367   -0.048    2.070
GRID          194         -0.184   -0.024    2.070
GRID          195          0.000    0.000    2.070
GRID          196          0.184    0.024    2.070
GRID          197          0.367    0.048    2.070
GRID          198          0.550    0.072    2.070
GRID          199         -0.699   -0.091    1.920
GRID          200         -0.466   -0.061    1.920
GRID          201         -0.233   -0.030    1.920
GRID          202          0.000    0.000    1.920
GRID          203          0.233    0.030    1.920
GRID          204          0.466    0.061    1.920
GRID          205          0.699    0.091    1.920
GRID          206         -1.496   -0.226    2.650
GRID            2          2.129    2.133   12.250
GRID           11          1.541    1.520   11.600
GRID           21          1.034    1.014   11.000
GRID           30          0.550    0.564   10.400
GRID           39          0.101    0.182    9.800
GRID           48         -0.317   -0.138    9.187
GRID           57         -0.677   -0.383    8.600
GRID           66         -0.998   -0.572    8.000
GRID           75         -1.271   -0.702    7.400
GRID           88         -1.490   -0.779    6.800
GRID          101         -1.621   -0.796    6.200
GRID          114         -1.642   -0.753    5.600
GRID          127         -1.572   -0.662    5.000
GRID          140         -1.435   -0.538    4.400
GRID          150         -1.208   -0.374    3.715
GRID          160         -0.917   -0.229    3.180
MAT1     1        1.6  E7          .35      .0004141
MPC      1        5      4         1.0      4        4        -1.0
MPC      1        6      4         1.0      4        4        -1.0
MPC      1        7      4         1.0      1        4        -1.0
PTRIA2   1        1      .01570
PTRIA2   2        1      .02827
PTRIA2   3        1      .01897
PTRIA2   4        1      .03380
PTRIA2   5        1      .02043
PTRIA2   6        1      .03623
PTRIA2   7        1      .02917
PTRIA2   8        1      .04440
PTRIA2   9        1      .03830
PTRIA2   10       1      .04253
PTRIA2   11       1      .03677
PTRIA2   12       1      .03397
PTRIA2   13       1      .02740
PTRIA2   14       1      .01673
```

⋮

PTRIA2 DATA IDENTICAL TO THAT FOR FORCED RESPONSE ANALYSIS

⋮

PTRIA2	289	1	.76263					
PTRIA2	290	1	.71047					
PTRIA2	291	1	.80953					
PTRIA2	292	1	.76303					
PTRIA2	293	1	.85827					
PTRIA2	294	1	.90487					
PTRIA2	295	1	.83280					
PTRIA2	296	1	.86773					
PTRIA2	297	1	.76483					
PTRIA2	298	1	.60217					
PTRIA2	299	1	.83203					
PTRIA2	300	1	.64773					
PTRIA2	301	1	.93570					
PTRIA2	302	1	.90603					
PTRIA2	303	1	.99047					
PTRIA2	304	1	1.02140					
PTRIA2	305	1	1.01607					
PTRIA2	306	1	1.03707					
PTRIA2	307	1	.89447					
PTRIA2	308	1	.97073					
PTRIA2	309	1	.43940					
PTRIA2	310	1	.62880					
PTRIA2	311	1	.45607					
PTRIA2	312	1	.62880					
PTRIA2	313	1	.89447					
PTRIA2	314	1	.97073					
PTRIA2	315	1	1.06800					
PTRIA2	316	1	1.08900					
PTRIA2	317	1	1.08900					
PTRIA2	318	1	1.06800					
PTRIA2	319	1	.97073					
PTRIA2	320	1	.89447					
PTRIA2	321	1	.62880					
PTRIA2	322	1	.43940					
PTRIA2	323	1	.43940					
PTRIA2	324	1	.62880					
PTRIA2	325	1	.89447					
PTRIA2	326	1	.97073					
PTRIA2	327	1	1.06800					
PTRIA2	328	1	1.08900					
PTRIA2	329	1	1.08900					
PTRIA2	330	1	1.06800					
PTRIA2	331	1	.97073					
PTRIA2	332	1	.89447					
PTRIA2	333	1	.62880					
PTRIA2	334	1	.43940					
PTRIA2	335	1	.55867					
PTRIA2	336	1	.70640					
PTRIA2	337	1	1.06620					
PTRIA2	338	1	1.06487					
PTRIA2	339	1	1.13913					
PTRIA2	340	1	1.06600					
PTRIA2	341	1	1.06600					
PTRIA2	342	1	1.13913					
PTRIA2	343	1	1.06487					
PTRIA2	344	1	1.06620					
PTRIA2	345	1	.70640					
PTRIA2	346	1	.55867					
SEQGP	1	9	2	8	3	7	4	4
SEQGP	5	2	6	1	7	10	8	11
SEQGP	9	20	10	19	11	18	12	17
SEQGP	13	16	14	15	15	12	16	5
SEQGP	17	3	18	21	19	30	20	29
SEQGP	21	28	22	27	23	26	24	25
SEQGP	25	22	26	13	27	6	28	39
SEQGP	29	38	30	37	31	36	32	35

```
SEQGP   33      34      34      31      35      23      36      14
SEQGP   37      47      38      48      39      46      40      45
SEQGP   41      44      42      43      43      40      44      32
SEQGP   45      24      46      56      47      57      48      55
SEQGP   49      54      50      53      51      52      52      49
SEQGP   53      41      54      33      55      66      56      67
SEQGP   57      65      58      64      59      63      60      62
SEQGP   61      58      62      50      63      42      64      76
SEQGP   65      77      66      75      67      74      68      73
SEQGP   69      72      70      68      71      59      72      51
SEQGP   73      86      74      87      75      85      76      84
SEQGP   77      83      78      82      79      78      80      69
SEQGP   81      61      82      60      83      79      84      71
SEQGP   85      70      86      88      87      99      88      98
SEQGP   89      97      90      96      91      95      92      91
SEQGP   93      92      94      81      95      80      96      103
SEQGP   97      94      98      93      99      89      100     100
SEQGP   101     110     102     109     103     108     104     107
SEQGP   105     104     106     114     107     106     108     105
SEQGP   109     115     110     118     111     117     112     90
SEQGP   113     101     114     111     115     121     116     120
SEQGP   117     119     118     116     119     127     120     128
SEQGP   121     132     122     130     123     139     124     145
SEQGP   125     102     126     112     127     122     128     134
SEQGP   129     133     130     129     131     131     132     142
SEQGP   133     150     134     157     135     144     136     156
SEQGP   137     169     138     113     139     123     140     135
SEQGP   141     146     142     140     143     141     144     143
SEQGP   145     154     146     167     147     179     148     124
SEQGP   149     136     150     147     151     151     152     152
SEQGP   153     153     154     155     155     166     156     178
SEQGP   157     125     158     137     159     148     160     158
SEQGP   161     160     162     161     163     162     164     163
SEQGP   165     165     166     164     167     168     168     170
SEQGP   169     172     170     173     171     174     172     175
SEQGP   173     176     174     177     175     126     176     149
SEQGP   177     159     178     171     179     180     180     182
SEQGP   181     183     182     184     183     185     184     186
SEQGP   185     181     186     187     187     190     188     191
SEQGP   189     192     190     193     191     194     192     188
SEQGP   193     195     194     197     195     198     196     199
SEQGP   197     200     198     201     199     189     200     196
SEQGP   201     202     202     203     203     204     204     205
SEQGP   205     206     206     138
SPC1    1       5       17      27      36      14      10      45
SPC1    1       5       23      54      37      112     146     185
SPC1    1       5       186     192     187     188     189     190
SPC1    1       5       191     193     194     195     196     197
SPC1    1       5       198
SPC1    1       123456  199     THRU    205
PARAM   LMODES  5
PARAM   KGGIN   1
AERO*   0               0.91639E+04     0.28149E+01     0.91790E-07     *AERO
*AERO
PARAM   IREF          60
PARAM   MAXMACH    0.950
PARAM   MINMACH    1.010
PARAM   NSEGS          8
PARAM   RFS       133.33
STREAML1      10     175     177     163     166     156
STREAML2      10       5    7.79   4.032   0.322   2.085   0.786.9179- 7+2      10
+2      10 10316.6  -14.88
STREAML1      20     138     140     129     131     121
STREAML2      20       5   17.14   4.675   0.108   3.508   0.827.9179- 7+2      20
+2      20 10859.5  -12.13
```

ORIGINAL PAGE IS
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```
STREAML1       30       99      101      103      105      111
STREAML2       30        5    18.27    4.876   -0.178    4.955     0.877.9179- 7+2     30
+2      30 11513.1    6.97
STREAML1       40       64       75       77       92      108
STREAML2       40        5    18.50    4.529   -0.312    6.339     0.826.9179- 7+2     40
+2      40 10848.5   26.04
STREAML1       50       37       49       60       70       82
STREAML2       50        5    21.10    3.799   -0.408    7.703     0.742.9179- 7+2     50
+2      50  9745.6   40.02
STREAML1       60       18       21       33       44       54
STREAML2       60        5    24.78    2.815   -0.570    8.894     0.698.9179- 7+2     60
+2      60  9163.9   47.18
STREAML1       70        1       13       14       15       27
STREAML2       70        5    31.02    1.805   -0.570    9.716     0.834.9179- 7+2     70
+2      70 10952.6   40.07
FLFACT  1       1.0
FLFACT  2       -45.0
FLFACT  3       .1      .3      .5      .7      .9      1.2     1.5
FLUTTER 1       KE      1       2       3       L       5
MKAERO2 -45.0   .05
MKAERO2 -45.0   .1
MKAERO2 -45.0   .3
MKAERO2 -45.0   .5
MKAERO2 -45.0   .7
MKAERO2 -45.0   .9
MKAERO2 -45.0   1.2
MKAERO2 -45.0   1.5
MKAERO2 -45.0   1.55
PARAM   MTYPE   COSINE
PARAM   KINDEX  0
PARAM   PRINT   YESB
PARAM   CTYPE   ROT
ENDDATA
```

INPUT DATA DECK FOR

APPLIED OSCILLATORY AIRLOADS GENERATION

```
  OSCILLATORY AIRLOADS FOR SR3 ADVANCED TURBOPROP
  CASE 6, TEST READING NO. 273, MACH .798
NLINES   7
FLOTYP   UNIFORM 10476.
NSEGS    8
RPS      133.33
INCANG   2.0
SSOUND   13128.
IREF     60
NASOUT   YES
MXMACH   .95
MNMACH   1.01
STREAML310      175      177      163      166      156
STREAML320      138      140      129      131      121
STREAML330      99       101      103      105      111
STREAML340      64       75       77       92       108
STREAML350      37       49       60       70       82
STREAML360      18       21       33       44       54
STREAML370      1        13       14       15       27
STREAML410      9.179E-8
STREAML420      9.179E-8
STREAML430      9.179E-8
STREAML440      9.179E-8.
STREAML450      9.179E-8
STREAML460      9.179E-8
STREAML470      9.179E-8
CORD2R   77     0        .0       .0       .0       .0       .0       1.       +C2R
+C2R     10.    -0.618   .0
GRDSET          77
GRID            1             1.808    1.839   12.250
GRID            3             2.376    2.347   12.250
GRID            4             2.625    2.558   12.250
```

⋮

GRID DATA IDENTICAL TO THAT FOR FORCED RESPONSE ANALYSIS

⋮

```
GRID           203            0.233    0.030    1.920
GRID           204            0.466    0.061    1.920
GRID           205            0.699    0.091    1.920
GRID           206           -1.496   -0.226    2.650
GRID             2            2.129    2.133   12.250
GRID            11            1.541    1.520   11.600
GRID            21            1.034    1.014   11.000
GRID            30            0.550    0.564   10.400
GRID            39            0.101    0.182    9.800
GRID            48           -0.317   -0.138    9.187
GRID            57           -0.677   -0.383    8.600
GRID            66           -0.998   -0.572    8.000
GRID            75           -1.271   -0.702    7.400
GRID            88           -1.490   -0.779    6.800
GRID           101           -1.621   -0.796    6.200
GRID           114           -1.642   -0.753    5.600
GRID           127           -1.572   -0.662    5.000
GRID           140           -1.435   -0.538    4.400
GRID           150           -1.208   -0.374    3.715
GRID           160           -0.917   -0.229    3.180
```

INPUT DATA DECK FOR

MODAL FORCED RESPONSE ANALYSIS

```
NASTRAN BANDIT = -1, SYSTEM(93)=1, FILES = (INPT, PLT2)
```

EXECUTIVE CONTROL DECK

```
ID          NASA,SR3PROP
APP         DISP
SOL         8
DIAG        8,14,21,22
TIME        10  $ CRAY-1 S
$
READFILE MFVAAET
$
CEND
```

CASE CONTROL DECK

```
$
TITLE = SR3 RESPONSE TO 1 PER REV OSC. AIRLOADS
SUBTITLE = NASA TEST READING NO. 273
LABEL = RESPONSE ANALYSIS
$
  SPC     = 1
  MPC     = 1
  METHOD  = 1
$
     DISP(SORT1,PHASE) = ALL
     STRESS(SORT1,PHASE) = ALL
$
$
$ NOTE ---
$    THE FOLLOWING DATA IS FOR
$    HUBTYP =  0     ( 0 = RIGID, 1 = FLEXIBLE )
$    FLOTYP =  0     ( 0 = UNIFORM, 1 = NON-UNIFORM )
$
FREQUENCY  =  1       $  SID OF FREQ BULK DATA CARD
$
   SUBCASE 1
     LABEL = K = 0 MODES, OSCILLATORY AIRLOADS PRESENT
     DLOAD = 1000
$
BEGIN BULK
```

OUTPUT FROM
AIRLOADS
PROGRAM

```
CORD2R  77      0       .0      .0      .0      .0      .0      1.      +C2R
+C2R    10.     -0.618  .0
CTRIA2  1       1       10      9       8
CTRIA2  2       2       11      10      8
CTRIA2  3       3       8       7       11
CTRIA2  4       4       12      11      7
CTRIA2  5       5       7       1       12
CTRIA2  6       6       13      12      1
CTRIA2  7       7       1       2       13
CTRIA2  8       8       14      13      2
CTRIA2  9       9       2       3       14
CTRIA2  10      10      15      14      3
CTRIA2  11      11      3       4       15
CTRIA2  12      12      16      15      4
CTRIA2  13      13      4       5       16
CTRIA2  14      14      17      16      5
CTRIA2  15      15      5       6       17
CTRIA2  16      16      20      19      18
CTRIA2  17      17      21      20      18
CTRIA2  18      18      18      9       21
CTRIA2  19      19      22      21      9
CTRIA2  20      20      9       10      22
CTRIA2  21      21      10      11      22
CTRIA2  22      22      23      22      11
CTRIA2  23      23      11      12      23
CTRIA2  24      24      24      23      12
CTRIA2  25      25      12      13      24
CTRIA2  26      26      25      24      13
CTRIA2  27      27      13      14      25
CTRIA2  28      28      14      15      25
CTRIA2  29      29      26      25      15
CTRIA2  30      30      15      16      26
CTRIA2  31      31      27      26      16
CTRIA2  32      32      16      17      27
CTRIA2  33      33      29      28      19
CTRIA2  34      34      30      29      19
CTRIA2  35      35      19      20      30
CTRIA2  36      36      31      30      20
CTRIA2  37      37      20      21      31
CTRIA2  38      38      32      31      21
CTRIA2  39      39      21      22      32
CTRIA2  40      40      33      32      22
CTRIA2  41      41      22      23      33
CTRIA2  42      42      23      24      33
CTRIA2  43      43      34      33      24
CTRIA2  44      44      24      25      34
CTRIA2  45      45      35      34      25
CTRIA2  46      46      25      26      35
CTRIA2  47      47      36      35      26
CTRIA2  48      48      26      27      36
CTRIA2  49      49      38      37      28
CTRIA2  50      50      28      29      39
CTRIA2  51      51      39      38      28
CTRIA2  52      52      40      39      29
CTRIA2  53      53      29      30      40
CTRIA2  54      54      30      31      40
CTRIA2  55      55      41      40      31
CTRIA2  56      56      31      32      41
CTRIA2  57      57      42      41      32
CTRIA2  58      58      32      33      42
CTRIA2  59      59      43      42      33
CTRIA2  60      60      33      34      43
CTRIA2  61      61      44      43      34
CTRIA2  62      62      34      35      44
```

CTRIA2	63	63	45	44	35
CTRIA2	64	64	35	36	45
CTRIA2	65	65	47	46	37
CTRIA2	66	66	37	38	47
CTRIA2	67	67	48	47	38
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SEQGP	205	206	206	138					
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SPC1	1	5	186	192	187	188	189	190	
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SPC1	1	123456	199	THRU	205				
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PARAM	KGGIN	1							
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PARAM    MINMACH      1.010
PARAM    NSEGS            8
PARAM    RPS         133.33
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*PARAMQ
PARAM*   BOV                  0.1535890E-03                                           *PARAMB
*PARAMB
STREAML1       10       175     177     163     166     156
STREAML2       10         5    7.79   4.032   0.322   2.085     0.786.9179- 7+2       10
+2     10 10316.6    -14.88
STREAML1       20       138     140     129     131     121
STREAML2       20         5   17.14   4.675   0.108   3.508     0.827.9179- 7+2       20
+2     20 10859.5    -12.13
STREAML1       30        99     101     103     105     111
STREAML2       30         5   18.27   4.876  -0.178   4.955     0.877.9179- 7+2       30
+2     30 11513.1      6.97
STREAML1       40        64      75      77      92     108
STREAML2       40         5   18.50   4.529  -0.312   6.339     0.826.9179- 7+2       40
+2     40 10848.5     26.04
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STREAML2       50         5   21.10   3.799  -0.408   7.703     0.742.9179- 7+2       50
+2     50  9745.6     40.02
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STREAML2       60         5   24.78   2.815  -0.570   8.894     0.698.9179- 7+2       60
+2     60  9163.9     47.18
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STREAML2       70         5   31.02   1.805  -0.570   9.716     0.834.9179- 7+2       70
+2     70 10952.6     40.07
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PARAM    KMIN             0
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*TB13A                                                                                *TB13B
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*TB13C         133.19667    1.0                   133.46333   1.0                     *TB13D
*TB13D         133.46333    0.0            1.0E10             0.0                     *TB13E
*TB13E   ENDT
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DPHASE*  12                              175              2          -141.70
DAREA*   11                              175              3  0.11429680E+00
DPHASE*  12                              175              3          -141.70
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DPHASE*  12                              177              1            47.47
DAREA*   11                              177              2  0.10394259E+01
DPHASE*  12                              177              2          -132.53
DAREA*   11                              177              3  0.10579464E+00
DPHASE*  12                              177              3          -132.53
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DAREA*   11                              166              2  0.46224357E+00
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DAREA*   11                              166              3  0.47047983E-01
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DAREA*	11	156	3	0.15030363E-01
DPHASE*	12	156	3	-95.35
DAREA*	11	138	1	0.57418266E+00
DPHASE*	12	138	1	16.20
DAREA*	11	138	2	0.19500249E+01
DPHASE*	12	138	2	-163.80
DAREA*	11	138	3	0.20845945E+00
DPHASE*	12	138	3	-163.80
DAREA*	11	140	1	0.60323770E+00
DPHASE*	12	140	1	29.39
DAREA*	11	140	2	0.20487010E+01
DPHASE*	12	140	2	-150.61
DAREA*	11	140	3	0.21900801E+00
DPHASE*	12	140	3	-150.61
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DPHASE*	12	129	1	55.33
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DPHASE*	12	129	2	-124.67
DAREA*	11	129	3	0.12319696E+00
DPHASE*	12	129	3	-124.67
DAREA*	11	131	1	0.21757333E+00
DPHASE*	12	131	1	75.16
DAREA*	11	131	2	0.73891717E+00
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DAREA*	11	105	2	0.48455145E+00
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DPHASE*  12                          27         3           49.89
ENDDATA
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NOTE: ALL DATA FROM AERO* CARD UPTO ENDDATA CARD ARE OUTPUT FROM AIRLOADS PROGRAM

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15. Supplementary Notes

16. Abstract

This report is a supplemental NASTRAN document for a new capability to determine the vibratory response of turbosystems subjected to aerodynamic excitation. Supplements to NASTRAN Theoretical, User's, Programmer's, and Demonstration Manuals are included.

Turbosystems such as advanced turbopropellers with highly swept blades, and axial-flow compressors and turbines can be analyzed using this capability. which has been developed and implemented in the April 1984 release of the general purpose finite element program NASTRAN.

The dynamic response problem is addressed in terms of the normal modal coordinates of these tuned rotating cyclic structures. Both rigid and flexible hubs/disks are considered. Coriolis and centripetal accelerations, as well as differential stiffness effects are included.

Generally non-uniform steady inflow fields and uniform flow fields arbitrarily inclined at small angles with respect to the axis of rotation of the turbosystem are considered as the sources of aerodynamic excitation. The spatial non-uniformities are considered to be small deviations from a principally uniform inflow. Subsonic and supersonic relative inflows are addressed, with provision for linearly interpolating transonic airloads.

17. Key Words (Suggested by Author(s))

Forced Vibrations, Aerodynamic Excitation, Turbosystems, NASTRAN, Finite Elements, Rotating Cyclic Structures

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